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THE TERTIARY ECHINOIDS OF SOUTH-EASTERN AUSTRALIA
II Cidaridae (2)

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Abstract

The following Australian Tertiary cidarids are described and figured: *Stereocidaris australiae* (Duncan), *S. cudmorei* sp. nov., *S. fosteri* sp. nov., *S. inermis* sp. nov., *S.* (?) *hispida* sp. nov., *S.* (?) *intricata* sp. nov., *S.* sp. A, *S.* sp. B, *S.* sp. C, *Goniocidaris murrayensis* C. & C., *G. praecipua* sp. nov., *G. tubaria hallettensis* subsp. nom. nov., *G.* (?) *pentaspinosa* C. & C., *Austrocidaris operta* sp. nov., *Delocidaris prunispinosa* (C. & C.) gen. nov., *Menocidaris compta* gen. et sp. nov. Fragmentary cidarid remains consisting of 3 different types of test and 7 different types of radiole are also listed and figured. The possible origins of the Ctenocidarina and Goniocidarina are reviewed, and it is concluded that both these groups were derived from the Stereocidarina in the Palaeogene. The *G. murrayensis-G. tubaria* lineage is discussed in detail.

Introduction

This paper concludes the description of the cidarids of the Tertiary of SE. Australia, the first section of which was given in Part I (Philip 1963b). Part III will deal with the Stirodonta, Aulodonta and the first section of the Camarodonta. The continued assistance of the individuals mentioned in Part I is gratefully acknowledged, in particular that of Mr Edmund D. Gill. A University of New England research grant has made continuation of the work possible.

Systematics

Genus **Stereocidaris** Pomel

Eucidaris Pomel 1883, p. 109.
Stereocidaris Pomel 1883, p. 110.
? *Typocidaris* Pomel 1883, p. 111.
Phalacrocidaris Lambert 1902, p. 27.
Anomocidaris Agassiz and H. L. Clark 1907, p. 30.
Sinaecidaris Fourtaw 1921, p. 9.
Stereocidaris Pomel, Mortensen 1928, p. 225 *et seq.* (*cum synon.*).
? *Compsocidaris* Ikeda 1939b, p. 160.
Stereocidaris Pomel, Fell 1954, p. 32-33.
(*Non*) *Eucidaris* Pomel *auctt.* (*fide* Philip, 1963).

Type Species: The type species of *Stereocidaris* is *Cidaris crestosa* Mantell, by subsequent designation of Lambert and Thiéry 1909, p. 31 (*fide* Mortensen 1928, p. 226). The type species of *Typocidaris* is *Cidaris malum* Gras, by monotypy. The type species of *Phalacrocidaris* is *Dorocidaris japonica* Döderlein, by original designation. The type species of *Anomocidaris* is *Cidaris* (*Stereocidaris*) *tenuispinus* Yoshiwara (= *Dorocidaris japonica* Döderlein), by original designation.

Diagnosis: Moderately large, often thick tested forms, typically with comparatively few, relatively high interambulacral plates. Scrobicules of uppermost one or more interambulacral plates rudimentary; primary tubercles usually smooth but may show traces of crenulation. Scrobicules generally incised. Often one or more of upper horizontal interambulacral sutures naked or depressed, ambital horizontal

sutures often grooved admedianly. Apical system usually dicyclic, with widely exsert oculars, and madreporite not obviously enlarged. Pores non-conjugate with separating wall forming a low, rounded projection.

Radioles variably ornamented, with shafts covered by longitudinally arranged spicules or granules, or sometimes ridges or laminae, between which is usually a spongy coat of cortical hairs. Distal termination often flared; collar usually very short; neck long and conspicuous.

Remarks: One peculiarity of the genus is that the apical system is apparently less caducous than in other cidarids so that it is not uncommonly preserved in fossil tests. The only cidarid test with the apical system intact known so far from the Tertiary of Australia is of *Stereocidaris inermis* sp. nov. described below.

There can be little doubt that both *Phalacrocidaris* and *Anomocidaris*—both based on *Stereocidaris japonica* (Döderlein)—should be regarded as synonyms of *Stereocidaris*. The distinguishing feature would be the degree of atrophy of the upper scrobicules of the interambulacra, but in fossil forms there is a whole gradation from species with only a single rudimentary scrobicule through to species comparable with *S. japonica*. Mortensen (1928) maintained *Phalacrocidaris* as a subgenus of *Stereocidaris* for this latter species in dealing with the living species of the genus, for then *S. japonica* stood well apart from the other living forms in its extremely rudimentary upper scrobicules. However, subsequently Mortensen (1939, p. 7-8, Pl. 2, fig. 1-4) described *S. reducta* which, in common with *S. japonica*, possesses considerably reduced upper scrobicules. Mortensen also noted that his new form in other respects showed close affinities with *S. microtuberculata* (Yoshiwara) (and, indeed, may be regarded as a subspecies of this form) so it would appear that even in living species the feature, although striking, is of no major taxonomic importance.

Compsocidaris Ikeda, based on *Compsocidaris pyrsacantha* (Ikeda 1939b, p. 160-4, Pl. 7-10) from the Bonin Is., is distinguished from the genus *Stereocidaris* only by its 'sparse tuberculation', so that its value is doubtful.

Whether or not *Typocidaris* should be regarded as a direct synonym of *Stereocidaris* is another matter. From the Mesozoic, particularly from the Cretaceous of Europe, there have been described a great number of *Stereocidaris*-like species which are typified by high interambulacral plates, rudimentary upper scrobicules, often bare or grooved horizontal sutures and, in general, non-conjugate pores. In the eventual grouping of these species, *Typocidaris* may well be retained for a group characterized by marked enlargement of the peristome, as is seen in the type species *Cidaris malum* Gras. In fact, a fairly obvious grouping of the great number of species of *Stereocidaris* can be achieved by utilizing test characters which, although apparently trivial, have been found to be of some taxonomic significance in dealing with living cidarids. In the absence of a detailed examination of specimens of these many species, one can do no more than point to the existence of these species groups, but it would seem that at least two groups (IV and V) should be accorded full generic status. The species groups are:

Group I—*Stereocidaris* S.S.

This group includes forms as diagnosed above; the peristome is smaller than the apical system, or, at the most, approximately the same diameter.

The group would seem to have its origin in the Jurassic; such species as *Cidarites moniliferus* Goldfuss and *Cidarites marginatus* Goldfuss (1824, p. 118-9, Pl. 39, fig. 7) belong here. The group is perhaps best known from the Cretaceous of Europe. Cotteau (1861-7) gives descriptions of the following forms which are all

species of *Stereocidaris* S.S.: *Cidaris Loryi* Cotteau, *Cidaris insignis* Gras, *Cidaris vesiculosa* Goldfuss, *Cidaris Rhothomagensis* Cotteau, *Cidaris Ligeriensis* Cotteau, *Cidaris sceptifera* Mantell, *Cidaris subvesiculosa* d'Orbigny, *Cidaris perlata* Sorignet, *Cidaris Vendocinensis* Cotteau, *Cidaris cretosa* Mantell, *Cidaris Merceyi* Cotteau, *Cidaris serrifera* Forbes.

As Cidaridae are poorly represented in the Cainozoic of Europe, only 3 species of *Stereocidaris* S.S. are known, 2 from the Eocene (*Phalacrocidaris Gauthieri* Lambert 1902, Pl. 19, fig. 23-7, and *Stereocidaris destefanni* d'Innocenti, *fide* Mortensen 1928, p. 230) and probably *Cidaris* (*Leiocidaris*) *Balestrai* Oppenheim (1902, p. 173, Pl. 9, fig. 1a-c) from the Oligocene. The genus is abundantly represented in the present day Indo-Pacific fauna, but it is known in the Atlantic only from a single form.

Although the upper Eocene species described below are the earliest occurrences of this group in the Australasian region, the genus was apparently established in the Indo-Pacific toward the end of the Cretaceous. Stoliczka (1873, Pl. 7) has described and illustrated a number of fragmentary forms (identified as European Cretaceous species of *Stereocidaris*) from rocks of Cenomanian to Santonian age in S. India. Farther W., from Persia, the Senonian *Cidaris persica* Cotteau, Gauthier and Douville (1895, Pl. 13, fig. 1-5) is undoubtedly a species of *Stereocidaris*. Lambert (1936) has described a cidarid as *Dorocidaris besairiei* (p. 23, Pl. 3, fig. 6) from sediments of reputed Campanian age in Madagascar. This appears to be a species of *Stereocidaris*, although Lambert describes the pores as subconjugate.

There appears to be little record of the genus throughout the Cainozoic of the Indo-Pacific region. Mortensen (1928, p. 300) suggested that a radiole from the Miocene of Java may belong to *Stereocidaris*; further, some fragmentary cidarids from the Miocene of Kachh, figured by Duncan and Sladen, are probably best included in the genus *Stereocidaris*. Gerth (1927, Fig. 1) has illustrated a cidarid from the Pliocene of Timor which appears to be a species of *Stereocidaris*. Considering its abundance in the Recent Indo-Pacific fauna, however, the genus is surprisingly rare.

Mortensen (1928) recognized 16 living species and 6 varieties all of which belong to *Stereocidaris* S.S. Subsequently (1932, 1934) he added 2 more species. These fall into 7 species groups which are:

1. *S. grandis* Döderlein from Japanese waters with the morphological variant *hyatorina* Mortensen. Allopatric forms of this are *S. hawaiiensis* Mortensen from Hawaii, *S. granularis* Mortensen from the Philippines (with its morphological variant *rubra* Mortensen), and *S. squamosa* Mortensen from the Indian Ocean.
2. *S. microtuberculata* (Yoshiwara) from the Sagami Sea. Its allopatric forms are *S. purpurescens* Mortensen from the Kei Is., *S. tubifera* Mortensen from the Philippines, *S. reducta* Mortensen from Indian waters, and *S. excavata* Mortensen from S. African waters.
3. *S. indica* Döderlein, an extremely variable species widely distributed through the Indian Ocean. Mortensen recognizes a morphological varient *philippinensis*. It seems very likely that *S. capensis* Döderlein, and *S. alcocki* (Anderson) are also varieties of *S. indica*. An allopatric form is *S. ingolfia* Mortensen from the West Indies and the N. Atlantic.
4. *S. leucacantha* Agassiz and Clark, from Hawaii, although resembling *S. grandis* to some extent, is apparently a good species.

5. *S. sceptiferoides* Döderlein, with its morphological variants *lanceolata* Mortensen and *lamellata* Mortensen, is a well-marked species from Japan.
6. *S. japonica* (Döderlein) is again a well circumscribed Japanese species.
7. *S. sulcatispinis* Mortensen, from the Kei Is. and Borneo.

Group II—*Typocidaris*

This group differs from Group I in that the peristome is markedly enlarged relative to the apical system, a feature seen in only two other cidaroid genera. Species, known only from the Cretaceous of Europe, include:

Cidaris malum Gras, Cotteau 1861-7, p. 198, Pl. 1045, fig. 1-12.
Cidaris pretiosa Desor, Cotteau 1861-7, p. 185, Pl. 1041.
Cidaris Lardyi Desor, Cotteau 1861-7, p. 190, Pl. 1043, 1049, fig. 1-4.
Cidaris Cenomanensis Cotteau 1861-7, p. 229, Pl. 1052.
Goniocidaris farringdonensis (Wright), Lambert 1892, p. 39, Pl. 2, fig. 3-5 [(*Non*) *Cidaris farringdonensis* Wright = *Stereocidaris* S.S.] = *Cidaris testiplana* Hawkins 1912, p. 531.

Most of the species referred by Lambert and Thiéry (1909, p. 151) to *Typocidaris* belong rather to Group I if they are allied to *Stereocidaris* at all (e.g. *Goniocidaris arduennensis* Lambert, *Typocidaris corbaricus* Lambert, *Cidaris farringdonensis* Wright).

Group III

Scrobicular tubercles with a definite raised ridge inside the mamelon, as in *Phyllacanthus*. Species of this group are known from the Cretaceous of Europe and probably N. America, and from the Paleocene of N. America.

Europe—
Cidaris Pyrenaica Cotteau 1861-7, p. 201, Pl. 1047-8, fig. 1-10.
Cidaris Forchammeri Desor, Cotteau 1861-7, p. 324, Pl. 1078-9, fig. 1-3.
North America—
Cidaris texanus Clark, Cooke 1953, Pl. 1, fig. 14, Cretaceous of Texas, probably belongs here.
Cidaris splendens (Morton), Cooke 1959, Pl. 1, fig. 10, Paleocene of New Jersey.
Cidaris sp. affin. *C. splendens* (Morton), Cooke 1959, Pl. 1, fig. 11, Paleocene of Alabama.

Group IV

Two N. American species with ridged scrobicular tubercles differ markedly from *Stereocidaris* S.S. in the conjugation of the pores and the apical system, which, at least in *S. hudspathensis*, possesses an enlarged madreporite. In *S. hudspathensis* the peristome is wider than the apical system, but in *Leiocidaris hemigranosus* they are approximately the same size. The species are:

Leiocidaris hemigranosus (Shumard), W. B. Clark and Twitchell 1915, p. 84, Pl. 10, fig. 1a-e; Pl. 11, fig. 1a-b, Cretaceous of the Gulf States, U.S.A.
Stereocidaris hudspathensis Cooke 1955, p. 89, Pl. 18, fig. 1-4, Cretaceous of Texas.

Group V

A single species appears to stand well apart from the other groups. This is *Cidaris foveata* Jackson (1922, p. 17-18, Pl. 1, fig. 6-7) from the probable Eocene of Jamaica. This imperfectly known species is described as possessing bare and grooved

horizontal interambulacral sutures (*Goniocidaris-Stereocidaris* feature), conjugate pores (cf. Group IV) and strongly crenulate tubercles.

The known geographic and stratigraphic distribution of the Stereocidarina is given in Fig. 3 appended to a discussion of the relationships and origin of the genus *Goniocidaris*.

DISTRIBUTION: The genus *Stereocidaris* (limited to Group I above) is very well represented in the Mesozoic of Europe, particularly the Cretaceous, but thereafter is rare, and is only represented by a single form in the living Atlantic fauna (which probably represents a recent re-invasion of the Atlantic by the genus). Although some Upper Cretaceous forms are known from the Indo-Pacific region, it is very poorly represented throughout the Cainozoic, but here the genus flourishes in Recent times. In the Australasian region the genus is very well represented in the Palaeogene. The occurrence in the Cretaceous of N. America (suggested by Mortensen 1928, p. 230, and recorded by Cooke 1955, p. 88-9) is based on forms which cannot be placed in *Stereocidaris* in a strict interpretation of the genus (i.e. Groups III and IV above).

Stereocidaris australiae (Duncan)

(Pl. LVIII, fig. 1-5; Fig. 2a, d, g-h)

Leiocidaris Australiae Duncan 1877, p. 45, Pl. 3, fig. 1-2.
Cidaris (*Stereocidaris*) *Australiae* (Duncan), Tate 1898, p. 411 (*partim*).
Cidaris (*Leiocidaris*) *australiae* Duncan, Chapman 1914, p. 145, Fig. 80a.
Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), Pl. 12, fig. 5-6, (*non*) fig. 1-4, (*non*) Pl. 15; H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).
(*Non*) *Leiocidaris Australiae* Duncan, Hutton 1887, p. 406.
(*Nec*) *Cidaris* (*Leiocidaris*) *australiae* Duncan, Tate 1894, p. 126.
= *Stereocidaris striata* (Hutton), Fell 1954, p. 33.

DIAGNOSIS: A species of *Stereocidaris* with up to 7 interambulacral plates in each vertical column, the upper one or 2 with rudimentary scrobicules. Scrobicules of the lower plates strongly sunken, and secondary tubercles very coarse. Interporiferous tracts ornamented with a regular series of marginal tubercles, usually with 2 smaller internal tubercles on larger plates.

Radioles cylindrical, often with trumpet-shaped distal terminations. Shaft ornamented by coarse longitudinal ridges bearing flattened, spur-like projections.

TYPE SPECIMEN: Holotype BM E42395 (the interambulacral zone originally figured by Duncan, *loc. cit.*). All available test fragments of this species, including the holotype, are labelled in the collection 'AW.5' or 'lower beds, AW.5'. They possess an adhering matrix of an impure limestone with rounded quartz and limonite fragments. It may reasonably be inferred that all specimens come from the Castle Cove Limestone, of 'Pre-Janjukian' age.

DESCRIPTION: The slightly sinuate ambulacra are about ⅓ the width of the interambulacra and are distinctly incised (Fig. 2a). The poriferous tracts are slightly wider than the interporiferous tracts. The marginal tubercles are well separated and form a regular vertical series, with a further vertical series of smaller internal tubercles. There are 2 internal tubercles on each of the larger plates (Fig. 2g), but the smaller plates away from the ambitus generally possess only one (Fig. 2d). The rounded pores are non-conjugate, and distinctly oblique, particularly in the smaller plates. The wall between the pores rises to a poorly defined crest, whereas the transverse ridge above the pores is sharp and well defined, and is at the level of the interporiferous tract.

Up to 7 interambulaeral plates are present in each vertical column, with the scrobiculcs of the upper one or two plates rudimentary. The fully developed scrobicules are mounted toward the centre of each column and are deeply incised, so that the small, smooth, perforate tubercles only just rise above the level of the interambulacral plates. The serobicules are in general well rounded and become only slightly ovate adorally. The scrobicular tubercles are not prominent as they are comparable in size to the secondary tubercles which cover the interambulacral plates. All the sutures are somewhat incised, and small pits may be present at the admedian ends of the horizontal ambital sutures.

MEASUREMENTS: Inferred measurements of the test from which P18913, an interambulacral zone, was derived are: h.d. *c.* 60 mm; v.d. *c.* 35 mm; width of apieal system *c.* 23 mm; width of peristome *c.* 17 mm.

ASSOCIATION OF TEST AND RADIOLES: The reasons for associating the radioles described below with *S. australiae* were given under the description of *Stylocidaris* (?) *chapmani* (Part I, p. 199).

DESCRIPTION OF RADIOLES: The shafts are cylindrical and possess up to 12 coarse longitudinal ridges which periodically bear flattened, spur-like projcetions. The distal termination is often sharply expanded to give a trumpet-shaped termination. The proximal portion is missing in all the available radioles.

SYNOPSIS OF MATERIAL:

Aire Coast:

AW.5 (probably Castle Cove Limestone, 'Pre-Janjukian'), P18900-2 (test fragments and radiole); 'lower beds', P18903-7, 9, 12-13 (test fragments); P18937-9 (radioles).

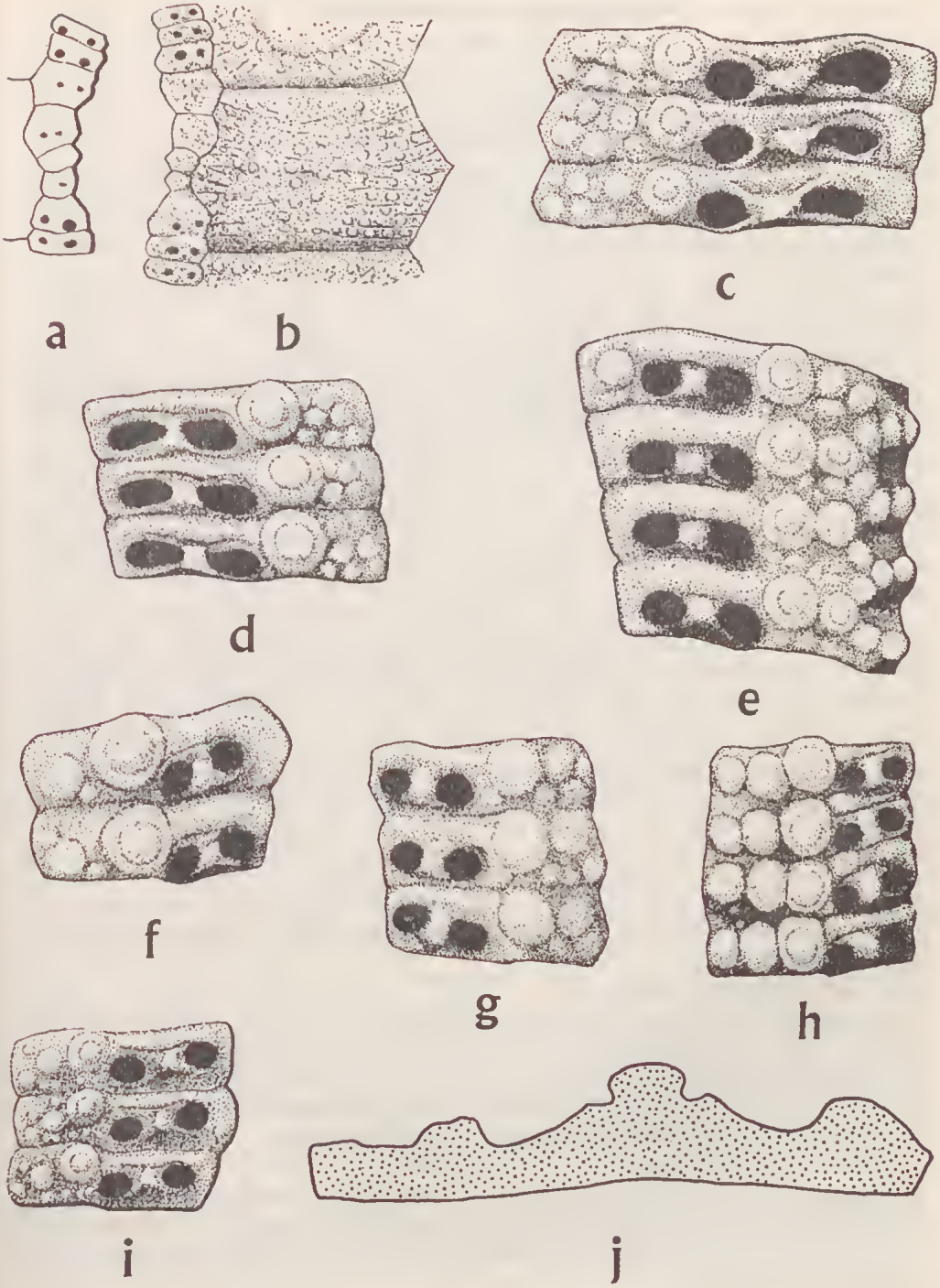
'Johanna R., hard limestones with occasional softer beds, dipping northerly' (? Castle Cove Limestone), P19006-12 (radioles).

'Point Flinders', P19751 (radiole), Lower Glen Aire Clays, 'Pre-Janjukian'.

REMARKS: Duncan (*loc. cit.*) originally deseribed this species as possessing conjugate pores, which has undoubtedly contributed much to the past uncertainty as to its identity. Chapman and Cudmore (loc. cit.), on the basis of topotype material, correctly pointed out that Duncan was in error; however, their own exceedingly liberal interpretation of the species has not assisted its subsequent discrimination. As interpreted here, the species is known only from the Aire Coastal section.

The widely-flared, cup-shaped terminations of the radioles are somewhat atypical for a species of *Stereocidaris*. However, they are known in the living form *S. tubifera* Mortensen, and appear to have been common in the Australian Palaeogene species of *Stereocidaris*, for they are seen in *Stereocidaris* sp. A. and other radioles which apparently belong to *Stereocidaris*-like forms.

FIG. 1—*Stereocidaris* spp. a-d, i-j, *Stereocidaris cudmorei* sp. nov. a, Internal. b, External view of abnormal ambulacrum of AUGD F15738. Note small podial pores do not extend to outside of test, × 3. c, Ambital ambulacrum of large specimen AUGD F15737, × 12. d, Ambital ambulacrum of AUGD F15731, × 12. i, Ambital ambulacrum of holotype P19365, × 10. j, Profile of ambulacrum and interambulacrum of holotype, × 6. e, *Stereocidaris* (?) *intricata* sp. nov. Ambital ambulacrum of holotype P22319, × 12. f-g, *Stereocidaris fosteri* sp. nov. f, Ambital ambulacrum of AUGD F15741, × 12. g, Ambital ambulacrum of holotype AUGD F15739, × 12. h, *Stereocidaris* (?) *hispida* sp. nov. Ambital abulacrum of holotype AUGD F15745, × 12.


a
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Stereocidaris cudmorei sp. nov.

(Pl. LX; Fig. 1a-d, i-j)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), Pl. 12, fig. 4, (*non*) fig. 1-3, 5-6, (*non*) Pl. 15.
? *Stylocidaris* sp. H. L. Clark 1946, p. 290.

Diagnosis: A large species of *Stereocidaris* with up to 9 interambulaeral plates in each vertieal eolumn, the serobieule of the upper one of whieh is redueed or rudimentary. Tubereles large and smooth, rising well above the level of the test. Interporiferous traets eomplexly ornamented. Median and horizontal ambulaeral sutures incised and naked to varying degrees or bearing pits at the admedian ends of the horizontal sutures.

Type Specimen: Holotype P19365, 'Aldinga, lower beds', Tortaehilla Limestone, Upper Eoeene.

Description: The ambulacra are about ½ of the width of the interambulacra and are only slightly sinuate. The poriferous traets (Fig. 1e-d) are approximately the same width as the interporiferous traets and are not ineised. The marginal tubereles are relatively small, although they form a regular vertieal series. Up to 6 irregularly plaeed internal tubereles are present on eaeh of the ambital ambulaeral plates, and are surrounded by closely spaeed granules, whieh also oeeur between the marginal tubercles. The pores are non-conjugate and elongate (partieularly the outer of eaeh pair) with the separating wall rising to a prominent crest. Bclow the erest and the pores the plate is deeply sunken. The transverse ridge above the pores is sharply delimited below by a deep furrow.

Up to 9 interambulaeral plates are present in eaeh vertieal series, with a rudimentary serobieule on the uppermost. The other scrobieules are ineised although the large smooth primary tubereles rise well above the level of the test (Fig. 1j). The perforations of the primary tubereles, partieularly those above the ambitus, tend to be somewhat elongate in the direetion of the vertieal axis. The serobieules are rounded above the ambitus, but beeome transversely oval toward the peristome, where they are confluent. The serobieular tubereles are not prominent and are only slightly larger than the surrounding seeondary tubereles. The interambulaeral midzone is variable in width, and may be marked by a naked zig-zag groove, whieh eontains the median suture. In some speeimens this is redueed to pits at the admedian ends of the horizontal sutures. Pits are usually present at the adradial ends of the same sutures. Apart from naked grooves and pits the midzones are eovered by elosely spaeed seeondary tubercles and numerous granules whieh tend to be arranged on horizontal ridges.

The radioles are unknown.

Measurements: The holotype was derived from a test with the following inferred measurements: h.d. *c.* 50 mm, v.d. *c.* 30 mm, diameter of peristome *c.* 17 mm, diameter of apieal system *c.* 23 mm, 10 ambulaeral plates opposite highest interambulaeral plate. Largest test fragments derived from tests with h.d. *c.* 70 mm; 14 ambulaeral plates opposite highest interambulaeral plate.

Synopsis of Material:

St Vineent Basin, Tortaehilla Limestone, Upper Eoeene: 'Maslin Bay', P19365-6, P20486, P20491, AUGD 15731-2, 6-7 and 20 other speeimens *ex* R. J. Foster Coll., AUGD 15738 and 2 speeimens AUGD Coll., 'Christies Beaeh', 1 speeimen AUGD Coll.

Blanche Point Marls, 'Pre-Janjukian', 'Witton's Bluff, Christies Beach', 1 specimen AUGD Coll.

ABNORMALITY: One specimen (AUGD F15738; Fig. 1a-b; Pl. LX, fig. 5) shows an interesting abnormality. The specimen is an interambulacral zone in which one of the interambulacral plates, apparently the second from the apical system, completely lacks a serobicule and tubercle. The secondary tubercles which cover the plates are arranged in sub-horizontal rows between the grooves which apparently represent the courses of the superficial nerve plexi. The adjacent ambulacral plates in general are not pierced, and are covered with secondary tubercles and grooves identical with those of the interambulacral plates. These ambulacral plates are irregular, both in size and shape, but are arranged in one vertical column, abutting against normal ambulacral plates above and below. Inside the test most of the test plates possess rudimentary depressions for the podia (Fig. 1a). The whole interambulacral zone is twisted in a fashion which would be consistent with the torsion resultant upon a relative decrease in the growth rate of the damaged ambulacrum. The interambulacral zone apparently came from a highly distorted test.

This abnormality is probably best explained as the result of severe damage and loss of plates (and podia) at an early growth stage, perhaps just after metamorphosis.

REMARKS: H. L. Clark (1946) has suggested that the specimen of this species illustrated by Chapman and Cudmore as *Stereocidaris australiae* 'is much more like *Stylocidaris* and probably represents an undescribed species of that or a related genus'. Although the generalized character of the test and radioles of *Stylocidaris* afford no satisfactory basis for its recognition in incomplete fossil material (Part I, p. 194), *Stylocidaris* lacks bare and pitted sutures (*Stereocidaris-Goniocidaris* characters). The rudimentary upper scrobicules are also suggestive of *Stereocidaris*, although they do occur in some species of *Stylocidaris*. On the other hand, the large number of interambulacral plates, a feature which characterizes the species, is not typical of *Stereocidaris*.

S. cudmorei shows considerable variation, particularly in the width of the interambulacral midzones and the development of naked interambulacral sutures. It is the most abundant cidarid of the Tortachilla Limestone and ranges up into the Blanche Point Marls.

Stereocidaris fosteri sp. nov.

(Pl. LIX, fig. 6; Pl. LXV, fig. 3; Fig. 1 f-g)

DIAGNOSIS: A moderately large species of *Stereocidaris* with up to 7 interambulacral plates in each vertical column, the scrobicule of the upper one of which is usually rudimentary. Tubercles comparatively large and smooth, with the scrobicules moderately incised so that the mamelons rise above the level of the test. Interporiferous tract ornamented by a regular series of large marginal tubercles with up to 2 smaller internal tubercles in each plate. Pores rounded, non-conjugate and slightly oblique. Upper horizontal interambulacral sutures bare and incised, and pits are developed at their admedian ends.

TYPE SPECIMEN: Holotype AUGD F15739, 'Maslin Bay', Tortachilla Limestone, Upper Eocene (*ex* R. J. Foster Coll.).

DESCRIPTION: The slightly sinuate ambulacra are about ⅓ the width of the interambulacra. The incised poriferous tract is similar in width to the interporiferous tract, which is ornamented with a regular series of marginal tubercles, with up to 2 small internal tubercles present on each plate, although smaller tubercles and

granules may be present (Fig. 1g). The somewhat oblique pores are non-conjugate and rounded with the separating wall rising to a well-marked protuberance. The transverse ridge is low and rounded.

Up to 7 interambulacral plates are present in each vertical column, the scrobicule of the uppermost of which is usually rudimentary. The other scrobicules are moderately incised, relatively large and rounded, with smooth tubercles with comparatively small mamelons which rise just above the level of the test. The scrobicular tubercles are rather prominent in comparison with the small secondary tubercles and granules which lie outside them. The interambulacral midzone is narrow and the interambulacral sutures tend to be incised, particularly the upper horizontal ones which are grooved. Small pits are usually present at the adradial and admedian ends of the horizontal sutures.

The radioles are unknown.

MEASUREMENTS: The holotype was derived from a test with the following inferred measurements: h.d. *c.* 35 mm, v.d. *c.* 20 mm, width of peristome *c.* 12 mm, width of apical system *c.* 20 mm; 15 ambulacral plates opposite the highest interambulacral plate.

SYNOPSIS OF MATERIAL:

'Maslin Bay', Tortachilla Limestone, Upper Eocene: AUGD 15739-41, and 3 other specimens *ex* R. J. Foster Coll., P20487.

REMARKS: *Stereocidaris striata* (Hutton) (Fell 1954, p. 33-4), from the Oligocene of New Zealand, apparently is a species very close to *S. fosteri*. From Fell's description it appears that *S. striata* has wider interporiferous tracts, less ambulacral plates opposite the interambulacral plates, and more rounded lower scrobicules. Although existing information suggests that the forms are closely related, they cannot be considered as subspecies until they become better known.

S. fosteri differs from its associate *S. cudmorei* in its small size, fewer interambulacral plates, rounded pores and less complexly ornamented interporiferous tracts, and generally narrow interambulacral midzones. It resembles more closely *S. australiae* but differs from this species in the scrobicules, which are less incised, and fewer of them are rudimentary. The secondary ornament is also coarser in *S. australiae*.

P19779, a small interambulacral zone with no locality differs from the available specimens of *S. fosteri* only in the partial crenulation of the tubercles, and so is provisionally identified as *S. fosteri*.

The species is named after Mr R. J. Foster whose extensive collection of echinoids has permitted satisfactory recognition of a number of the rarer cidarid species.

Stereocidaris inermis sp. nov.

(Pl. LIX, fig. 1-3, 7-8; Fig. 2 b-c, e-f)

Goniocidaris inermis MS. Tate 1898, p. 411 (*fide* Chapman and Cudmore 1934, p. 129).
Cidaris (*Stereocidaris*) *Australiae* Duncan, Tate 1898, p. 411 (*partim*).
Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), Pl. 12, fig. 1-3, (*non*) fig. 4-6; (*non*) Pl. 15; H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).
(*Non*) *Leiocidaris Australiae* Duncan 1877, p. 45, Pl. 3, fig. 1-2.

DIAGNOSIS: A species of *Stereocidaris* with 8 or 9 interambulacral plates in each vertical column, the scrobicules of the upper 3 to 5 of which are rudimentary. Interambulacral sutures bare and deeply incised, with the admedian ends of the horizontal

sutures often deeply grooved at ambitus. Poriferous tracts markedly sunken; interporiferous tract with each plate ornamented by a regular series of marginal tubercles augmented by up to 3 irregularly placed internal tubercles.

TYPE SPECIMEN: Holotype AUGD T363 (a test bearing R. Tate's MS label *'Goniocidaris inermis'* and illustrated by Chapman and Cudmore 1934, Pl. 12, fig. 1-2 as *'Stereocidaris australiae'*), 'Aldinga', Tortachilla Limestone, Upper Eocene.

DESCRIPTION: The deeply incised ambulacra are about ⅓ the width of the interambulacra and are distinctly sinuate. The poriferous tracts of the ambulacra are approximately the same width as the interporiferous tracts and are markedly incised. The relatively small marginal tubercles of each plate form a regular vertical series. Two or even 3 irregularly placed internal tubercles are also present on each of the ambital ambulacral plates (Fig. 2b, f). The pores are non-conjugate and distant, with the separating wall rising to a definite elevation. They are round and slightly oblique. The transverse ridge above the pores is low.

8 or 9 interambulacral plates are present in each vertical series. The scrobicules, mounted toward the centre of each column, are rudimentary or absent on the upper 3, 4 or 5 interambulacral plates. Below the ambitus the scrobicules are deeply incised and ovate, and almost confluent adorally. Because of the deepness of the scrobicules the relatively small, smooth primary tubercles rise only slightly above the level of the test (Fig. 2c). The scrobicular tubercles are small and closely spaced so that only rarely are secondary tubercles interposed between them. The uppermost interambulacral plates are covered by very regularly spaced, comparatively large secondary tubercles which show a tendency to be arranged in horizontal series. Similar secondary tubercles cover the midzone and the adradial zone of the lower plates. The sutures are bare and incised while at the ambitus the admedian ends of the horizontal sutures may form pits (Pl. LIX, fig. 8).

The apical system is regularly dicyclic, with the oculars widely exsert. One genital plate, apparently the madreporite, is very slightly enlarged (Fig. 2c; Pl. LIX, fig. 7). All the plates of the apical system are covered by secondary tubercles similar in size and spacing to those of the upper coronal plates.

Both the ambulacral and interambulacral plates are remarkably thick (Fig. 2c). No radioles can be associated with this species.

MEASUREMENTS: The holotype (a small test which has been slightly crushed increasing the original h.d. at the expense of the v.d.) has the following dimensions: v.d. 18·5 mm, h.d. 35·0 mm, width of apical system 15 mm (43% of h.d.), width of peristome 11·5 mm (33% of h.d.); 10-12 ambulacral plates opposite an ambital interambulacral plate.

SYNOPSIS OF MATERIAL:

Tortachilla Limestone, Upper Eocene: 'Glauconitic limestone of the Aldinga Cliffs' (Tate 1898, p. 411), AUGD T362 (a test fragment derived from a test of h.d. approximately 50 mm—the specimen compared by Tate (1898) with the type specimen of *S. australiae* (Duncan) and identified as that species, and subsequently illustrated as such by Chapman and Cudmore 1934, Pl. 12, fig. 3); 'Aldinga', P20493 (a test fragment, undoubtely from the Tortachilla Limestone, labelled '*Goniocidaris inermis* Tate'); AUGD T363, AUGD 15744 and 5 other specimens *ex* R. J. Foster Coll.

REMARKS: This species is readily separable from the other Australian Tertiary species of *Stereocidaris* by the striking atrophy of the scrobicules of the interambula-

cral plates above the ambitus. In this feature it is comparable with the Recent species *S. japonica* (Döderlein) and the Cretaceous species *S. merceyi* (Cotteau).

A certain variation obtains in the available specimens, not only in the number of upper interambulacral plates which bear rudimentary scrobicules, but also in their degree of atrophy. The holotype possesses rudimentary tubercles on the 3 uppermost interambulacral plates, whereas one specimen (Chapman and Cudmore 1934, Pl. 12, fig. 3) shows all trace of the scrobicules to be lost on the 4 uppermost plates. That all specimens are conspecific is beyond doubt, although Tate (1898) identified one as *Stereocidaris australiae* (Duncan) and another as his *Goniocidaris inermis*. Chapman and Cudmore identified all as *S. australiae*.

The test of *S. inermis* closely resembles that of the living species *S. japonica* (Döderlein). This is most striking in comparing the holotype (a small specimen) of *S. inermis* with Mortensen's (1928) description and figures of *S. japonica*. The most obvious difference lies in the fact that only the upper 2 or 3 scrobicules are rudimentary in *S. japonica*. Furthermore, in *S. inermis*, both the apical system and peristome are relatively wider, and the interporiferous tracts possess slightly more complex ornament. Other differences which may be noted are that *S. inermis* may possess pits at the admedian ends of the horizontal sutures (a feature apparently absent in *S. japonica*), the remarkably thick test of *S. inermis* has not been reported in *S. japonica*, and apparently *S. inermis* grew to a larger size.

Chapman and Cudmore (p. 129), in discussing the apical system of the holotype of this species, state that 'all the plates are present, even the anal plate, which is depressed into the underlying matrix'. At present, however, the specimen is without trace of periproctal plates.

Stereocidaris (?) hispida sp. nov.

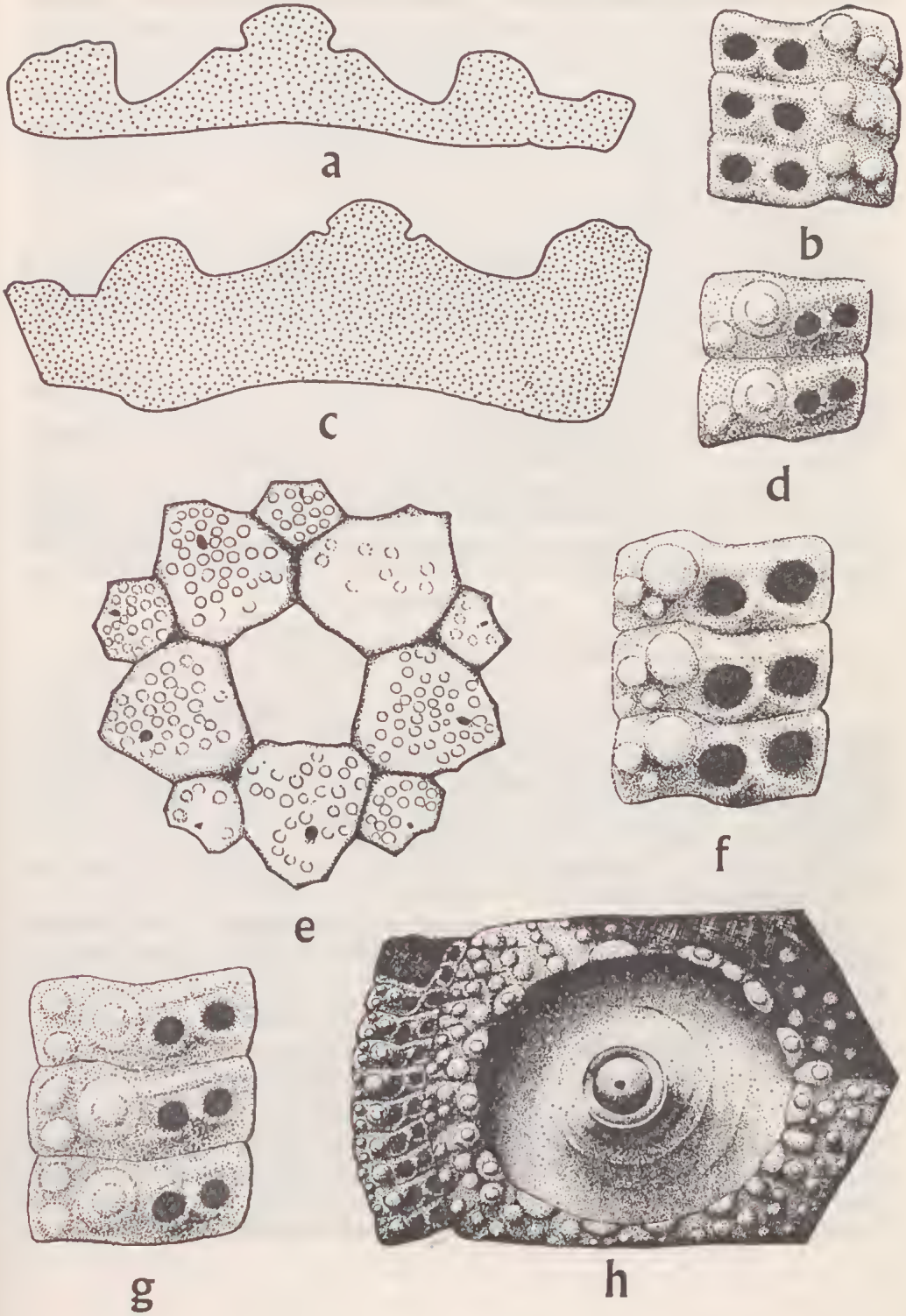
(Pl. LXI, fig. 8-9; Fig. 1h)

DIAGNOSIS: A small *Stereocidaris*-like form with up to 6 interambulacral plates in each vertical column, and with the uppermost scrobicule in each zone rudimentary. Tubercles comparatively small and smooth, with small scrobicules. Secondary tubercles coarse and closely spaced. Interporiferous tracts with regular series of marginal tubercles and with two series of large internal tubercles. Interambulacral sutures slightly sunken and pits may be developed at the admedian ends of the horizontal sutures.

TYPE SPECIMEN: Holotype AUGD 15745, 'Maslin Bay', Tortachilla Limestone, Upper Eocene.

DESCRIPTION: The slightly sinuate ambulacra are about ¼ of the width of the interambulacra. The sunken poriferous tracts (Fig. 1h) are approximately ⅔ of the width of the interporiferous tracts. The large marginal tubercles are almost contiguous and form a regular vertical series. On each plate up to two enlarged internal tubercles may be present, and these may also form regular vertical series. The pores are rounded and non-conjugate. The transverse ridge above the pores is wedge-shaped and bounded below by a deep furrow.

FIG. 2—*Stereocidaris* spp. a, d, g-h, *Stereocidaris australiae* (Duncan). a, Profile of ambulacrum and interambulacrum of P18905, × 6. d, Sixth and seventh ambulacral plates from peristome of P18904, × 15. g, Ambital ambulacrum of P18905, × 15. h, Ambital interambulacral plate and adjacent ambulacrum of holotype BM E42395, × 5. b-c, e-f, *Stereocidaris inermis* sp. nov. b, Ambital ambulacrum of holotype AUGD T363, × 5. c, Profile of ambulacrum and interambulacrum of P20493, × 6. e, Apical system of holotype. The madreporite is apparently the slightly enlarged genital lacking surface detail, × 4. f, Ambital ambulacrum of P20493, × 15.


a
b
c
d
e
f
g
h

Up to 6 interambulacral plates are present in each vertical series, with a reduced or rudimentary scrobicule on the uppermost of each zone. The other scrobicules are rounded and small, and are mounted adradially so that the interambulacral midzone is wide. The scrobicular tubercles are enlarged and closely spaced and possess elongated mamelons. The relatively large mamelons of the smooth primary tubercles rise well above the level of the test. The secondary tubercles are relatively large and closely spaced. The interambulacral sutures are slightly sunken, and pits may be developed at the admedian ends of the horizontal sutures. The upper horizontal sutures tend to be bare.

The radioles are unknown.

MEASUREMENTS: AUGD F15746 was derived from a test with the following inferred measurements: h.d. *c.* 20 mm, v.d. *c.* 12 mm, diameter of peristome *c.* 11 mm, diameter of apical system *c.* 14 mm; 10 ambulacral plates opposite highest interambulacral plate. AUGD 15745 was derived from a test with h.d. *c.* 27 mm.

SYNOPSIS OF MATERIAL:

'Maslin Bay', AUGD F15745 and 3 other specimens *ex* R. J. Foster Coll., Tortachilla Limestone, Upper Eocene.

'Seaford', AUGD F15746 and 2 other specimens *ex* R. J. Foster coll., Port Willunga Beds, Janjukian to Batesfordian; one specimen *ex* AUGD Coll.

REMARKS: This species is best included in *Stereocidaris* although its small size and coarse tuberculation are not typical of the genus. Knowledge of the radioles would provide additional evidence of its generic position. To some extent it resembles *Delocidaris prunispinosa*, but is much more coarsely ornamented. No other comparisons can be suggested.

Stereocidaris (?) intricata sp. nov.

(Pl. LIX, fig. 4; Fig. 1e)

DIAGNOSIS: A species of *Stereocidaris* with 6 or 7 interambulacral plates in each vertical column, and with the uppermost scrobicule rudimentary. Median interambulacral and upper horizontal sutures bare and incised. Poriferous tracts slightly sunken; interporiferous tracts ornamented by a regular series of marginal tubercles augmented by a complex grouping of up to 6 internal tubercles. Admedian ends of horizontal ambulacral sutures with conspicuous pits.

TYPE SPECIMEN: Holotype and only known specimen P22319, 'Aldinga, lower beds', Tortachilla Limestone, Upper Eocene.

DESCRIPTION: The ambulacra are slightly sinuate and about ⅓ the width of the interambulacra. The sunken poriferous tract is slightly narrower than the interporiferous tract. The marginal tubercles form a regular vertical series. The remainder of the interporiferous tract bears a complex arrangement of up to 6 internal tubercles on each plate (Fig. 1e). Conspicuous pits are developed at the admedian ends of the horizontal ambulacral sutures. The rounded pores are horizontal and non-conjugate with the separating wall rising to a protuberance. The horizontal ridge above the pores is low.

Up to 7 interambulacral plates in each vertical column, with the scrobicule of the uppermost rudimentary. On the other plates the scrobicules are comparatively small and rounded and deeply incised, so that the small smooth primary tubercles rise just above the level of the test. The scrobicular tubercles are small and closely spaced, and the secondary interambulacral ornament consists of dense secondary

tubercles and granules. The upper horizontal sutures are bare and incised, as in the median interambulacral suture, so that a prominent median zig-zag furrow is present. Pits are developed at the adradial ends of the horizontal ambital sutures.

The radioles of this species are not known.

MEASUREMENTS: P22319 was derived from a test with the following inferred measurements: h.d. *c.* 40 mm, v.d. *c.* 22 mm, width of peristome *c.* 15 mm, width of apical system *c.* 20 mm.

REMARKS: This species, in its rudimentary upper scrobicules and general characters, is suggestive of the genus *Stereocidaris*, and, indeed, it resembles *S. australiae* in its general appearance. The bare median interambulacral suture, and the pits developed at the admedian ends of the horizontal ambulacral sutures, however, are atypical of this genus, and rather indicate affinities with *Goniocidaris*. *S.*(?) *intricata* thus belongs to the group of Eocene and Oligocene forms which are transitional ambulacral sutures (some varieties of *S. cudmorei, Stereocidaris* sp. C) and forms with pits developed along the median ambulacral sutures in addition (Corona sp. 2, *S.* (?) *intricata*).

When more complete material of these intermediate forms becomes available (particularly when the nature of the radioles becomes known) it may prove desirable to erect a genus to accommodate some of these species. The present material suggests, however, that in dealing with this plexus of Palaeogene forms, characters which may be accorded generic merit in living cidarids lack the stability to enable worthwhile subdivisions.

No similar forms are known outside the Australian Tertiary.

Stereocidaris sp. A

(Pl. LXI, fig. 2-3; Pl. LXII, fig. 4-5; Pl. LXV, fig. 2)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-130 (*partim*), Pl. 15, fig. 32a-b (6 radioles), (*non*) fig. 34-6; (*non*) Pl. 12; H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).

(*Non*) *Leiocidaris Australiae* Duncan 1877, p. 45, Pl. 3, fig. 1-2.

DESCRIPTION: Radioles cylindrical or slightly tapered, with the shaft ornamented by small, sharp denticles usually arranged in longitudinal series or mounted on longitudinal ridges. There are usually between 12 and 20 such series or ridges on each radiole. The distal termination may be slightly flattened and is flared and trumpet-shaped in all the available specimens. The cortex between the denticles on well preserved specimens is covered by a thick anastomosing mass of strong cortical hairs, which may almost envelop the denticles (Pl. LXII, fig. 5). The neck is prominent and is usually between 0·5 to 1·5 times the diameter of the shaft. The collar is of comparable height and expands slightly to the milled ring. The acetabulum may show traces of crenulation (Pl. LXI, fig. 2). In transverse section the cortex layer is relatively thick.

Isolated interambulacral plates from the same locality as the radioles (apparently derived from a small test with h.d. *c.* 30 mm) includes one plate on which the scrobicule is rudimentary (Pl. LXII, fig. 4). On the other plates the scrobicules are usually deeply incised, with the small perforate tubercle rising just above the level of the plate. The tubercle of one of the plates shows traces of crenulation. The secondary tubercles are usually of similar size to that of the rounded scrobicular tubercles. Facets of 14 ambulacral plates are present along the adradial edge of the highest interambulacral plate.

MEASUREMENTS: P15978 has the following measurements: length 31 mm;

maximum diameter of the shaft 3·3 mm; maximum diameter of the neck 3 mm; maximum diameter of the milled ring 4·2 mm.

SYNOPSIS OF MATERIAL:

'Aire Coast, Point Flinders, AW.1', Lower Glen Aire Clays, Pre-Janjukian:
P19343-53 (test fragments); P19578-96 (radioles); P19730-50 (radioles); P19699-704 (radioles).

REMARKS: One of the isolated interambulacral plates (P19344, Pl. LXII, fig. 4, top left) differs from the others in possessing a shallow scrobicule, a somewhat larger tubercle and more prominent scrobicular tubercles. Conceivably it could belong to a different species.

The collars of the radioles are notably long for a species of *Stereocidaris*. Although this form is apparently distinct from the other Australian species of *Stereocidaris*, the incomplete nature of the available material prevents positive identification.

Stereocidaris sp. B

(Pl. LXIV, fig. 7, 9-11)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-130 (*partim*), (*non*) figs; H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).
Chondrocidaris clarkii Chapman and Cudmore 1934, p. 141-2 (*partim*), (*non*) figs; H. L. Clark 1946, p. 248 (*partim*); Fell 1954, p. 11 (*partim*).
(*Non*) *Leiocidaris Australiae* Duncan 1877, p. 45, Pl. 3, fig. 1-2.
(*Nec*) *Phyllacanthus clarkii* (Chapman and Cudmore).
(*Nec*) *Menocidaris compta* gen. et sp. nov.

DESCRIPTION: Radioles cylindrical or fusiform, and thick and stout. The shaft shows extreme variation in ornament from forms which merely possess longitudinally aligned denticles, through to others in which the denticles are augmented by spur-like projections, which in turn may coalesce into high, irregular lamellae running most of the length of the shaft. The radioles usually show a tendency for the ornament to be less developed along one (adoral?) side; immediately above the neck the ornament is also more rudimentary. The surface of the shaft possesses a sparse coat of simple cortical hairs, which apparently extended about half way up the flanks of the lamellae, but was absent from the denticles. The distal termination, known in only one radiole, is slightly expanded and cupped. The neck is short, usually less than the diameter of the shaft, while the collar is often only half this diameter. As a consequence the milled ring is only slightly expanded. In a number of radioles (Pl. LXIV, fig. 7) the acetabulum is partly crenulate. In transverse section the cortex layer is thin.

Isolated interambulacral plates (derived from a test with h.d. *c.* 50 mm) associated with the radioles in the collection show that the rounded scrobicules may be small in relation to the size of the plate. The scrobicules are well incised, so that the large primary tubercle hardly rises above the level of the plates; in no case is the scrobicule rudimentary. The secondary tubercles outside the scrobicular circle are comparable in size to the rounded, closely spaced scrobicular tubercles, and may be distinctly mamillate. They are widely and irregularly spaced. The surface of the plates between the secondary tubercles is marked by a well developed system of grooves radiating from the scrobicule. Facets of 19 ambulacral plates are present along the adradial edge of the highest interambulacral plate.

MEASUREMENTS: P18959 has the following measurements: length, 40 mm; maximum diameter of the shaft, 4·7 mm; diameter of neck, 2·8 mm; diameter of milled ring, 3·4 mm.

SYNOPSIS OF MATERIAL:

Aire Coast, Browns Ck Clays, Pre-Janjukian:
'Hamilton Ck', Horden Vale, P18940-6 (test fragments); P18947-86 (radioles); 'Browns Ck, right side of valley ½ mile from mouth', P19910-11 (radioles); 'Browns Ck', P20147-50, 52 (radioles).

REMARKS: The highly ornate radioles in particular distinguish this large and well-marked species of *Stereocidaris*. Again, however, the incomplete material prevents naming of the form.

Stereocidaris sp. C

(Pl. LXVI, fig. 3, 8)

DESCRIPTION: Ambulacra slightly sinuate with the poriferous and interporiferous tracts equal in width. The moderately large marginal tubercles form a regular vertical series. A small internal tubercle is also present diagonally below the marginal tubercle on each plate. The pores are slightly oblique and non-conjugate, with the separating wall rising to a distinct elevation. The horizontal ridge above the pores is well defined.

Up to 7 interambulacral plates are present in each vertical column. The interambulacral midzone is narrow and is marked by a prominent zig-zag furrow, and the upper horizontal sutures are also incised. Secondary interambulacral ornament is confined to a narrow circlet of small tubercles immediately adjacent to the scrobicular circle. The scrobicules of the uppermost interambulacral plates are rudimentary; the lower scrobicules are shallow and the primary tubercles rise well above the level of the test. The upper tubercles are partially crenulate with the crenulation confined to the adapical portions of the platforms.

MEASUREMENTS: AUGD F15742 was derived from a test with the following inferred measurements: h.d. *c.* 27 mm, v.d. *c.* 15 mm, width of peristome *c.* 10 mm, width of apical system *c.* 12 mm; 11 ambulacral plates opposite the highest interambulacral plate.

SYNOPSIS OF MATERIAL:

AUGD F15742, the only known specimen, is from the Tortachilla Limestone (Upper Eocene) at Aldinga (*ex* R. J. Foster Coll.).

REMARKS: This species is characterized by the prominent median interambulacral furrow, which is suggestive of *Goniocidaris*. In other respects, however, the species is typical of *Stereocidaris*, so that the form is to some extent intermediate between the two genera. Although readily separable from other described species, the available specimen does not warrant formal naming.

Genus **Goniocidaris** Agassiz & Desor

Goniocidaris L. Agassiz and Desor 1846, p. 33.
Stephanocidaris A. Agassiz 1863, p. 18.
Discocidaris Döderlein 1885, p. 10.
Petalocidaris Mortensen 1903, p. 25.
Cyrtocidaris Mortensen 1927, p. 67.
Aspidocidaris Mortensen 1928a, p. 67.
Goniocidaris Agassiz and Desor, Mortensen 1928, p. 149 *et. seq.* (*cum synon.*).
Adelcidaris Cotton and Godfrey 1942, p. 217.
Goniocidaris Agassiz and Desor, Fell 1954, p. 37.

TYPE SPECIES: Some confusion exists as to the identity of the type species of *Goniocidaris*. The type species given by L. Agassiz and Desor is *Cidarites gera-*

noides Lamarck, which as Mortensen (1928, p. 161) points out, is not recognizable as a species of *Goniocidaris*. However, Agassiz and Desor's figure of *Goniocidaris geranoides* is indistinguishable from *Cidarites tubaria* of Lamarck, so that most subsequent authors have taken *C. tubaria* as the type species of the genus. Strict application of the laws of priority would mean that *Stephanocidaris* Agassiz (based on *Cidarites tubaria* Lamarck) should replace *Goniocidaris* but, as there is a clear case for action by the International Commission of Zoological Nomenclature to stabilize the widely used name *Goniocidaris* under Article 70, it is retained for the group of *Cidarites tubaria*.

Because of the uncertainty as to the nature of *Cidarites geranoides*, more recently Cotton and Godfrey (*loc. cit.*) proposed the genus *Adelcidaris*, based on *Cidarites tubaria*.

Diagnosis: Small, often rather fragile forms, usually with depressed tests. Ambulacra normally wide, with narrow poriferous tracts in which the pores are close together and separated by a distinct wall. Both ambulacral and interambulacral horizontal sutures grooved medianly and often connect with a vertical furrow containing the median suture. Primary tubercles smooth. Radioles extremely variable and usually highly ornamented, often with an expanded disc at the base and/or a trumpet-shaped distal termination. The cortical hairs in general fine, rarely anastomosing, and often very long with free terminations. Collar usually short.

Remarks: Mortensen (1928) recognized 5 subgenera (*Goniocidaris* S.S., *Discocidaris, Petalocidaris, Cyrtocidaris* and *Aspidocidaris*) through which were distributed the 14 species which he then recognized. 3 more living species have been described subsequently. The subgenera, based largely on the character of the radioles, are of very little value, as was admitted by Mortensen and, indeed, they were subsequently abandoned by him (e.g. 1939). If polytypic species are recognized within the genus there are but 5 well marked living species of the genus. These may be listed as:

G. tubaria (Lamarck) from SE. Australia, with the morphological variant *impensa*, and the allopatric subspecies *umbraculum* from New Zealand.

G. florigera Agassiz, known only from the Kei Is. The allopatric forms of this species are *spinosa* from Ambon Bay and *biserialis* from the Sagami Sea and the Suruga Gulf. *Goniocidaris belinensis* Mortensen (1932, p. 148), from the Beli Sea, may also be regarded as an allopatric subspecies of *florigera*.

G. mikado (Döderlein) from the Sagami Sea, with the allopatric form *peltata* from the Kei Is. and Termate (2 specimens). Mortensen's identification of hybrids (*mikado* × *rosea*) with *Rhophalocidaris rosea* suggests very close genetic relationship between *Rhophalocidaris* and *Goniocidaris*.

G. tenuispinosa Mortensen, from the Philippines, with its 2 morphological variants *tuberculata* and *major*.

G. clypeata (Döderlein) from the Sagami Sea and N. Japan, with the allopatric forms *fimbriata* from the Malaya Archipelago and the Kei Is., and the closely related *crassa* (based on 4 specimens) from Mindinao, *sigobae* (based on 3 specimens) dredged from 5° 3′ S. 119° E., *australiae* from the SE. Australian coast, the more recently described *G. indica* Mortensen (1939, p. 3) from Indian waters, and *G.* (*Aspidocidaris*) *parasol* Fell (1958, p. 32, 34, Pl. 3, fig. B; Pl. 5, fig. b) from New Zealand. Also in this group belongs *alba* from Satsuma, Japan, based on one specimen.

The relations and distributions within this large group are imperfectly known. From the present knowledge it seems *alba* and *clypeata* are sympatric. Thus it would appear that *G. alba* has become sufficiently differentiated from *clypeata* (by geographic isolation through such forms as *fimbriata* and *crassa*) as to be able to reinvade the range of *clypeata* in Japanese waters where the two forms may coexist as good species. The morphological separation of *australiae* suggests that perhaps this should also be accorded the rank of a full species.

These species groups are very well differentiated and sympatric for most of their ranges. Hybrids have been reported between some of the species groups (e.g. *mikado* × *clypeata*).

DISTRIBUTION: The genus thus is strictly Indo-Pacific and Australasian in its present day distribution, and is particularly well represented in the Malayan and Japanese seas.

Apart from the Australian species, a number of fossil forms have been described which have been placed in *Goniocidaris*. Mortensen (1928, p. 145-6) reviewed these and concluded that *Goniocidaris affinis* Duncan and Sladen and *Cidaris hallaensis* d'Archiac and Haime (Duncan and Sladen 1883, p. 51-53, pl. 8, fig. 7-9), from the Miocene of Kachh, are the oldest goniocidarinids. Mortensen also considered that radioles figured from the same locality suggest a species of *Goniocidaris*. Duncan and Sladen's fig. 8-11, 13-14 (all probably of the one species), rather than a true species of *Goniocidaris*, recall the Eocene and Oligocene Australian species which are here included in *Stereocidaris*, in particular *S. cudmorei*. The radioles are also similar to the Australian Palaeogene forms. The test, as described and figured, lacks naked or pitted sutures along the median zone of the ambulacra, and the pores are widely separated (both *Stereocidaris*-like features). From the present knowledge the Indian Miocene form is best regarded as a species of *Stereocidaris*.

The radioles illustrated by Duncan and Sladen (1888, Pl. 57, fig. 1-14) from the Pliocene Makran Series (similar radioles have been recorded by Curric 1924, from the Aru Is.), also considered by Mortensen to be suggestive of the genus *Goniocidaris*, appear to be far too massive for a member of this genus, even considering *G. tubaria*. Some possess verticellate ornament, so that a relationship with *'Plococidaris'* is suggested, but, at present, the affinities of these radioles are obscure.

Subsequent to Mortensen's review, Grant and Hertlein (1938, p. 6) have noted that H. L. Clark, who examined specimens of the Oligocene Californian species *Cidaris branneri* Arnold (*non* White), 'considered its characters resembling those of the genus *Goniocidaris*'. This comparison is not apparent in any published description or figure of the species.

Fell (1954) appears to have accepted the forms illustrated by Duncan and Sladen as true species of *Goniocidaris* although he writes (p. 17)—'By the Miocene the genus (i.e. *Goniocidaris*) was represented by two species in northern India (Gaj)'. As none of the Gáj cidarids resembles *Goniocidaris*, this is seemingly an error for the Kattywar forms mentioned by Mortensen. From the data available from Australia, Fell gave a map which showed the genus *Goniocidaris* arising in the Eocene of southern Australia, extending to New Zealand in the Oligocene, thence across Australia to India in the Miocene, in the Pliocene extending farther to the Persian Gulf, and finally to Japan and E. Africa in Recent times.

Of the data on which this figure is based it may be observed:

1. The Eocene record of the genus in Australia is based on Chapman and Cudmore's (1934) listing of their *G. prunispinosa* and *G. pentaspinosa* from the 'lower

beds, Aldinga'. Reynolds (1953) had previously shown these to have a considerable stratigraphic range—from Upper Eocene to Middle Miocene. Most of Chapman and Cudmore's cidarids were derived from the upper part of the sequence. The oldest species of *Goniocidaris* in the present collection are of Janjukian age.

2. No extra-Australasian fossil occurrences can be regarded confidently as species of *Goniocidaris*. If the Miocene Indian form(s) be admitted, then, by the same criteria, so must *Goniocidaris jorgensis* de Loriol (1902, p. 8, Pl. 1, fig. 14-15) from the reputed Eocene of Patagonia. This form is based on isolated interambulacral plates, with bare median sutures.

It does seem likely, however, from the present available evidence that the Goniocidarina (and the Ctenocidarina) did arise in the Palaeogene of the Australasian region. In the Indo-Pacific region, where knowledge of the early Tertiary and Mesozoic faunas is so incomplete, it would be extremely hazardous to argue the time and place of origin of a group from its first known occurrence. But, in this instance, an obvious ancestral group can be distinguished, namely the Stereocidarina. Indeed, in the Palaeogene of Australia, there exists a whole spectrum of forms the gross morphology of which connect the genera *Stereocidaris* and *Goniocidaris*.

The Upper Eocene *Stereocidaris cudmorei* possesses incised and bare median interambulacral sutures, a feature unknown in any other species of *Stereocidaris* but typical of *Goniocidaris*. Furthermore, *Stereocidaris australiae* has radioles with strongly cup-shaped terminations, as has also *Stereocidaris* sp. A. Such radioles are very rare in the living species of *Stereocidaris* (partially developed in *S. tubifera* Mortensen) and are atypical for the genus; however, they characterize *Goniocidaris*. The tests of the early species here included in *Goniocidaris* reflect their heritage, for here the *Stereocidaris*-like features of the rudimentary upper arcoles of the upper interambulacral plates (a character lost in the *Goniocidaris murrayensis-G. tubaria* lineage) and the bare upper horizontal interambulacral sutures are present.

In this context, mention should be made of *Goniocidaris prunispinosa* Chapman & Cudmore. This small form lacks the incised sutural grooves which characterize the Goniocidarina and, to a lesser extent, the Stereocidarina and, thus, the test recalls the general morphology of the Ctenocidarina, although the pores are not oblique. Stereocidarine characters are seen in the rudimentary scrobicules of the upper interambulacral plates and the partial crenulation of the tubercles (a feature seen in the Ctenocidarina but not in the Goniocidarina). On the other hand, the highly ornate radioles with cup-shaped terminations strongly suggest *Goniocidaris*. Below the species is set apart as a new genus, *Delocidaris*, which combines stereocidarine, goniocidarine, and ctenocidarine features.

More obvious affinities with the Ctenocidarina are indicated by the species described below in the genus *Austrocidaris*. Here the pores are so oblique that an affinity with the Ctenocidarina is beyond reasonable doubt.

Thus, this record suggests that, although no direct ancestral species can be indicated, in the Oligocene some contribution was made by the Stereocidarina to the Goniocidarina. In this plexus of species the origins of the largely Antarctic group, the Ctenocidarina, can also be seen.

Mayr (1954) in discussing speciation in echinoids, and examining the Neogene records of some N. American living species, concluded 'that most lines have existed since the Lower Pliocene (12 million years ago) . . .' and 'a period of 20-25 million years might be in many cases a more precise estimate of the length of time required for the development of a new species'.

These figures would seem to speak against the late Palaeogene origin of such

diverse cidarid groups as the Goniocidarina and the Ctenocidarina as is suggested by the Australian species. However, it must be remembered that Mayr's figure is based on stable lineages which, because of ecological equilibrium and active competition, have reached a conservative rate of speciation. There can be no doubt, during the time when a group was actively exploring new ecological habitats (i.e. during diversification), the rate of speciation was much greater. The present day wealth of clypeasteroid echinoids (which arose at the end of the Cretaceous) establishes this.

Fig. 3 summarizes the phylogeny and distribution suggested by the Australian Tertiary species and records from elsewhere in the world. The Roman numerals refer to the species groups discussed under *Stereocidaris*.

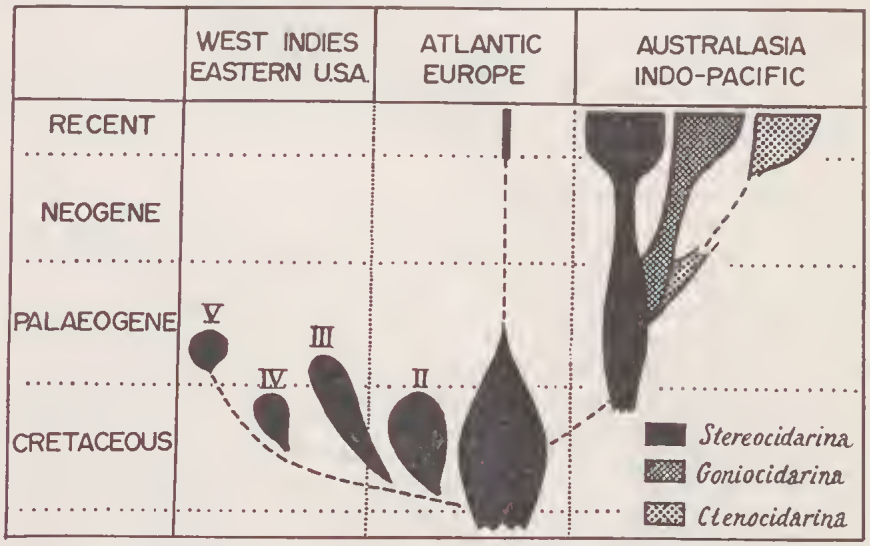


FIG. 3—Suggested phylogeny and distribution of the Stereocidarina, Goniocidarina and Ctenocidarina. Living members of the Ctenocidarina are confined largely to Antarctic waters. The Roman numerals refer to species of groups used in discussion of *Stereocidaris*.

Goniocidaris murrayensis Chapman & Cudmore

(Pl. LXII, fig. 2-3, 6-12; Pl. LXIV, fig. 5-6; Pl. LXVI, fig. 4, 6-7, 9-12; Fig. 4 a-f)

Goniocidaris pentaspinosa Chapman and Cudmore 1928 *in* Chapman 1928, p. 91-2 (*partim*), Pl. 11, fig. 74g, (*non*) fig. 74 a-f.
Goniocidaris murrayensis Chapman and Cudmore 1934, p. 138-9, Pl. 14, fig. 20-2.
Goniocidaris prunispinosa Chapman and Cudmore 1934, p. 135-7, (*partim*), (*non*) figs.
Goniocidaris pentaspinosa Chapman and Cudmore 1934, p. 137-8, (*partim*), Pl. 14, fig. 18, (*non*) fig. 19.
Goniocidaris murrayensis Chapman and Cudmore, H. L. Clark 1946, p. 292-3; Fell 1954, p. 11.

DIAGNOSIS: A moderately large species of *Goniocidaris* usually with median ambulacral and interambulacral furrows of variable width but which may be reduced to median pits, particularly below the ambitus. Upper horizontal interambulacral sutures usually bare and uppermost scrobicule rudimentary. Interporiferous tract ornamented by a regular series of small, marginal tubercles, with up to 5 closely spaced internal tubercles on each plate. 7 ambulacral plates opposite the highest interambulacral plates; up to 7 interambulacral plates in each vertical column.

Radioles comparatively long and somewhat fusiform with short collars and poorly defined necks. Shafts ornamented by irregularly placed, distally directed denticles.

TYPE SPECIMEN: Holotype, P4674, a small test originally designated by Chapman and Cudmore (1934, p. 18) and illustrated (op. cit.) Pl. 14, fig. 21-2, 'Lower Murray Cliffs', ? Morgan Limestone.

DESCRIPTION: The test is depressed with slightly incised ambulacral tracts.

The ambulacra are distinctly sinuate and up to ⅓ the width of the interambulacra. The ambulacral plates (Fig. 4b, d) are low, with the interporiferous tract slightly wider than the poriferous tract. The poriferous tract is sunken although the ridge above the pores on each plate is well defined. The slightly oblique pores are rounded and well separated with the wall between each pair rising to a poorly defined elevation. The median suture is deeply incised and furrows extend outward from this along the horizontal ambulacral sutures, imparting to the furrow a zig-zag appearance. The interporiferous tract is ornamented by a regular series of small marginal tubercles mounted toward the top of each plate. These are joined by up to 5 small internal tubercles on each plate.

The interambulacral plates are comparatively high, particularly above the ambitus. The scrobicules are rounded although those of the lower plates tend to be transversely elliptical and the lowermost may be confluent; that of the uppermost plate of each interambulacral zone is rudimentary. The scrobicules are not deeply incised and the bosses are conspicuous and rise well above the level of the test. The scrobicular tubercles are conspicuous and may tend to overhang the scrobicules. The secondary tubercles outside the scrobicular circle are small and densely spaced and form subhorizontal series across the wide median zones of the larger plates. The median interambulacral suture is deeply grooved in most specimens, but in some this groove does not continue below the ambitus, and rarely the groove may be completely replaced by a series of pits at the admedian ends of the horizontal sutures (Pl. LXII, fig. 12). The upper horizontal sutures are furrowed but toward and below the ambitus this furrow is closed so that only 'V'-shaped pits are present at both ends of the horizontal sutures.

MEASUREMENTS: Holotype test: h.d. 13 mm, v.d. 6 mm, diameter of apical system 6·5 mm, diameter of peristome 5 mm. Largest test fragments were derived from tests with h.d. *c.* 25 mm. In larger specimens up to 7 interambulacral plates in each vertical column; 7 ambulacral plates opposite the highest interambulacral plate. Longest radiole (incomplete) 28 mm long.

RADIOLES: Chapman and Cudmore did not recognize the radioles of this species. The radioles here associated with the test in this species were identified by them as either *G.* (?) *pentaspinosa* or *Delocidaris prunispinosa.*

However, there is little doubt that the present association is correct. The radioles are readily separated from those of the above species, and are co-extensive with the test fragments.

DESCRIPTION OF RADIOLES: The radioles are cylindrical or slightly fusiform and tapering. The collar is usually short, so that the milled ring is only slightly expanded. The neck, when visible, is long, almost equal to the diameter of the shaft. The shaft is usually ornamented by small, numerous, irregularly placed distally directed denticles, the interspaces between which are covered by apparently simple, serially arranged cortical hairs. The distal termination of the shaft may be slightly flared or cup-shaped, although it is lost on most of the available specimens. Some radioles

appear to have possessed flattened distal terminations. In transverse section the cortex layer is thin.

SYNOPSIS OF MATERIAL:

'½ mile S. of Lethbridge', Maude Beds, P18531, ? Janjukian.
'Longford', ? Longford Limestone, P19979 (test fragment). 'Holdings old quarry, Torresdale, near Mt Gambier', Gambier Limestone, P19462-4, Janjukian or Longfordian.
'Le Grand's Quarry, Glencoe', GSV 58924-6 (15 test fragments); 'Marl pit 250 yds W. Brocks Quarry', GSV 58927-8, Gippsland Limestone, Batesfordian.
From localities along the Murray R. Cliffs, S.A.:
Mannum Formation, Longfordian.
'Wongulla', P19309-26, P19286-9 (test fragments); 'Lower Murray Cliffs', (? Morgan Limestone), holotype.
Morgan Limestone, Batesfordian and Balcombian.
'Morgan', P13719 (paratype test fragment), P19810 (test fragment), P19865-80 (radioles), P19915-7 (test fragments); '4 miles below Morgan', P19385 (radiole), P19883 (radiole), P19978 (test fragment).
'Murgheboluc, Sec. 4A', P19884 (radiole), P19926-7, P19918 (test fragments), Balcombian.
'Seaford', Port Willunga Beds, AUGD F15728-9, 33-5 and 30 specimens *ex* R. J. Foster Coll., Janjukian to Batesfordian.
'Tramway cutting (Geol. Surv. Loc. 6), Mississippi Ck', P18419-26 (radioles), Cheltenhamian.
'Roadside cutting, left bank Tambo R., downstream from Swan Reach bridge', i.e. Tambo R. Formation, P19076-120 (radioles), Cheltenhamian.

REMARKS: Chapman and Cudmore (1934) identified specimens with narrow interambulacral midzones and with few secondary tubercles as belonging to their *G. pentaspinosa*. Examination of all available material, particularly that from the Port Willunga Beds, established that only one variable species is represented in the material. The wide variation exhibited by species, coupled with the incomplete nature of the material from all but a few horizons, serves to obscure the changes which may be present in this long ranging form. The tests from the Batesfordian and older horizons are usually small and often worn.

The radioles attributed to this species are from localities along the Murray R. cliffs, and the younger Bairnsdalian-Cheltenhamian limestones of Gippsland. The Gippsland examples possess noticeably longer collars, and the ornament is much more subdued (cf. Pl. LXVI, fig. 10, 11).

These observations suggest that probably a number of subspecies may, at a later stage, be found to be present in this species, but their recognition is not justified at present.

The species is closely related to *G. tubaria hallettensis* and the lineage is discussed under that subspecies.

Goniocidaris praecipua sp. nov.

(Pl. LXI, fig. 10-12; Fig. 4i, k, m)

DIAGNOSIS: A species of *Goniocidaris* with wide interambulacral midzone and small, closely spaced secondary tubercles. Scrobicules of upper interambulacral plates either reduced in size or rudimentary. Poriferous tract sunken; interporiferous tract complexly ornamented with up to 10 small internal tubercles.

TYPE SPECIMEN: Holotype, P22316, a crushed test from the 'Polyzoal limestone, beach N. of Bird Rock, Torquay', i.e. '*Cellepora* Limestone', Puebla Formation, Longfordian. P18607, a test fragment from the same locality, is the only other known specimen.

DESCRIPTION: The ambulacra (Fig. 4m) are only slightly sinuate and about ⅓ the width of the interambulacra. The poriferous tracts are sunken so that they appear as grooves in the test. The interporiferous tract is almost twice as wide as the poriferous tract. On each plate the ridge above the pores is discernible, although not well developed, so that the lower portion of each plate in the poriferous tract is further sunken. The pores are comparatively small and round and are slightly oblique with the wall between them rising to a low protuberance. On each plate the ornament of the interporiferous tract consists of a small marginal tubercle mounted toward the upper margin of the plate and augmented by up to ten small, closely mounted internal tubercles which lack serial arrangement. 'V'-shaped pits are developed at the median ends of the horizontal ambulacral sutures, although the median suture is not itself sunken or naked.

The interambulacral plates (Fig. 4k) possess relatively small, well rounded scrobicules. On the uppermost plates the scrobicules are rudimentary, whereas those of the lower plates are moderately incised, and mounted toward the adradial side of each column. The bosses rise just above the level of the test to the small smooth mamelons. The scrobicular tubercles are small and insignificant as are also the closely spaced secondary tubercles. A prominent zig-zag groove is developed along the median interambulacral suture. The margins of this are irregular and scalloped, imparting a ragged appearance, accentuated by the varying depth of the floor of the groove. The upper horizontal sutures are incised for their entire length, but toward and below the ambitus the incised portions are confined to the adradial and admedian ends of the sutures, where they appear as lateral extensions of the median furrow.

Radioles are unknown.

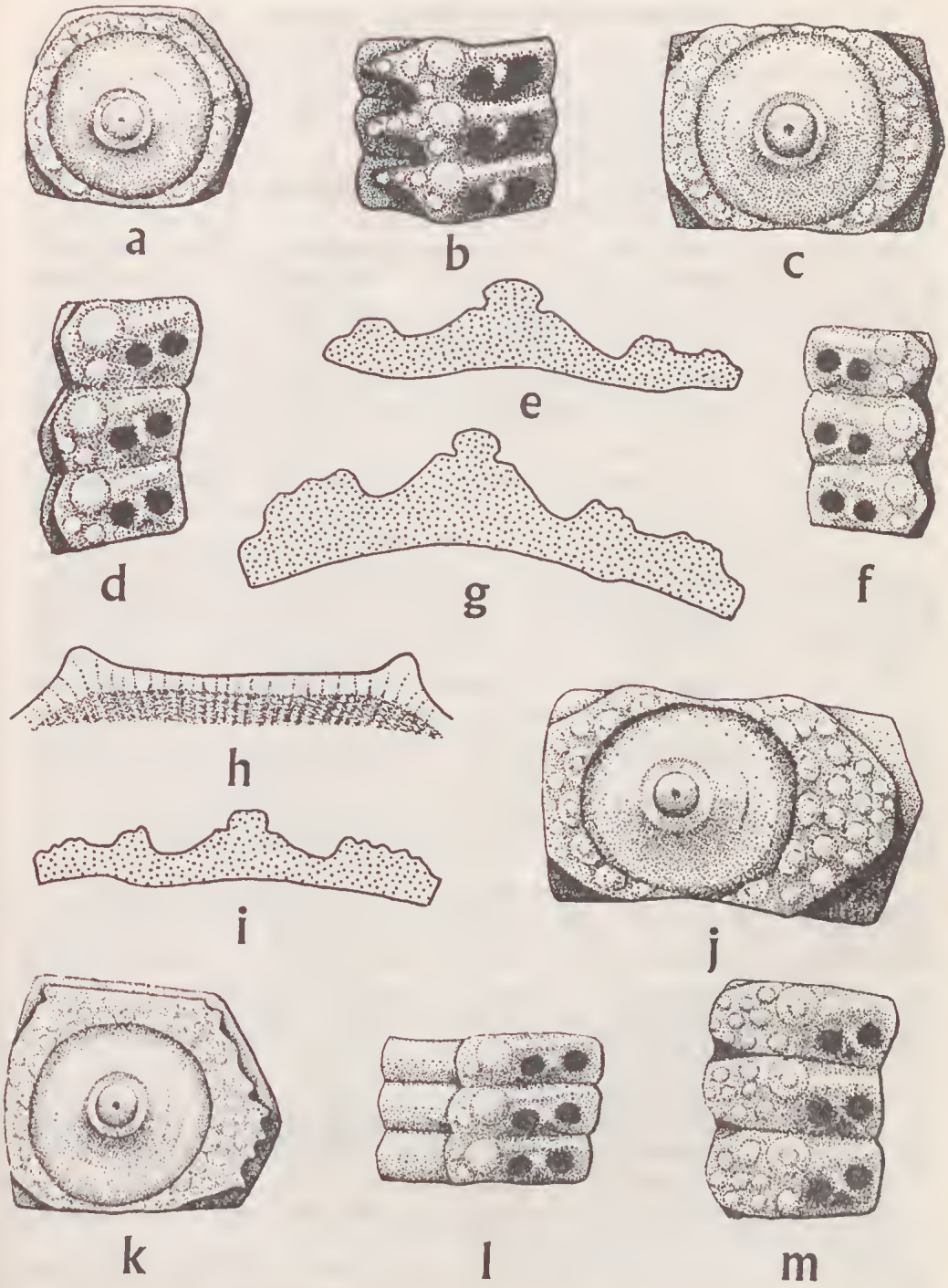
MEASUREMENTS: The holotype, a crushed test, has the following maximum dimensions: h.d. 18·5 mm; v.d. 8 mm; diameter of apical system 9·5 mm; diameter of peristome 8 mm; 6-7 interambulacral plates in each vertical column; 6 ambulacral plates opposite the highest interambulacral plate.

REMARKS: This species stands well apart from the other species of *Goniocidaris*, particularly in the very complexly ornamented interporiferous tracts of the ambulacra. The oblique pores suggest some relationship with *Austrocidaris* but this feature is much less marked than in *A. operta* sp. nov.

Goniocidaris tubaria (Lamarck)

Cidarites tubaria Lamarck 1816, p. 57.
Goniocidaris tubaria (Lamarck), Mortensen 1928, p. 156-163, Pl. 12, fig. 1-7; Pl. 13, fig. 10-11; Pl. 69, fig. 4; Pl. 78, fig. 1-6 (*cum synon.*).

FIG. 4—*Goniocidaris* spp. a-f, *Goniocidaris murrayensis* Chapman & Cudmore. a, Ambital interambulacral plate of P19288, × 6. b, Ambital ambulacrum of P19810, × 15. c, Ambital interambulacral plate of P19810, × 10. d, Ambital ambulacrum of P19288, × 12. e, Profile of ambulacrum and interambulacrum of P19288, × 10. f, Ambulacrum of GSV 58908, × 12. g, j, l, *Goniocidaris tubaria hallettensis* subsp. nom. nov. g, Profile of ambulacrum and interambulacrum of P19449. × 6. j, Interambulacral plate P19449, × 6. l, Ambulacrum of P19451, × 10, h, *Goniocidaris* (?) *petaspinosa* Chapman & Cudmore. Cortical layer in transverse section, × 40. i, k, m, *Goniocidaris praecipua* sp. nov. i, Profile of ambulacrum and interambulacrum of P18607, × 6. k, Interambulacral plate of P18607, × 6. m, Ambital ambulacrum of P18607, × 15.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Goniocidaris tubaria hallettensis nom. nov.

(Pl. LXVI, fig. 1-2, 12; Pl. LXVII, fig. 4-6; Fig. 4g, j, 1)

Goniocidaris mortenseni Chapman and Cudmore 1934, p. 139-140, Pl. 14, fig. 23, 27; H. L. Clark 1946, p. 291; Fell 1954, p. 11.

(*Non*) *Goniocidaris mortenseni* Koehler 1900, p. 816, *fide* Koehler 1901, p. 5, Pl. 1, fig. 1; Pl. 2, fig. 2; Pl. 3, fig. 17; Pl. 4, fig. 29; Pl. 5, fig. 30.

= *Notocidaris mortenseni* (Koehler), Mortensen 1909, p. 27.

DIAGNOSIS: A subspecies of *G. tubaria* with high ambulacral plates, so that 7 or 8 are opposite the highest interambulacral plates.

TYPE SPECIMEN: P13720, the test fragment originally selected and figured (Chapman and Cudmore 1934, Pl. 14, fig. 23) as holotype of *G. mortenseni*, from the Hallett Cove Sandstone, Middle Pliocene.

DESCRIPTION: The ambulacra (Fig. 4l) are straight, and up to ⅓ of the width of the interambulacra. The poriferous tract is about ½ of the width of the interporiferous tract. The rounded pores are well spaced, slightly oblique, and non-conjugate with the wall between rising to a distinct elevation. The transverse ridge above the pores is prominent. The median ambulacral zone is marked by a deep furrow, usually about ⅓ of the width of the abulacra. In this furrow the horizontal sutures are incised, imparting a ladder-like appearance. The ornament of the interporiferous tract consists of a regular series of almost contiguous marginal tubercles, joined on each plate by a few small and irregularly placed internal tubercles.

The interambulacral plates (Fig. 4j) are low, usually with rounded scrobicules, which may be transversely oval, with a tendency toward confluence. The scrobicules are shallow, and are mounted adradially so that the interambulacral midzone is wide. The bosses are conspicuous, and rise well above the level of the test to the small smooth tubercles. The scrobicular circles are conspicuous, with several rows of smaller tubercles outside them in the midzones of the larger plates. A very deep zig-zag furrow marks the interambulacral midzone. This may be as wide as the width of the scrobicules, and extends outwards as grooves along the horizontal sutures. The adradial ends of the horizontal sutures are also depressed and bare.

RADIOLES: The radioles originally associated with this test undoubtedly belong here. They are the only goniocidarinids known from the type formation, and both the test and radioles are closely similar to the living species of *G. tubaria*.

DESCRIPTION OF RADIOLES: The radioles are comparatively massive and cylindrical or slightly tapered. Both the neck and collar are short and the milled ring is but slightly expanded. The shaft is usually ornamented by fairly small, distally directed thorns, which are larger and more numerous distally. The distal termination may be slightly flared or even cup-shaped. The cortical hairs appear to be simple (or have simple terminations) and are serially arranged. In transverse section the cortical layer is very thin. Many of the radioles from the type horizon are of a purplish colour, which could be their original colouration.

MEASUREMENTS: Largest test fragments (e.g. P19451) derived from tests with h.d. *c.* 35 mm. 7 or 8 ambulacral plates opposite highest interambulacral plates; *c.* 9 or 10 interambulacral plates present in each vertical column.

SYNOPSIS OF MATERIAL:

'Tramway cutting, Mississippi Ck (Geol. Surv. Loc. 6)', P18417-8 (radioles), Tambo R. Formation, Cheltenhamian.

From the Middle Pliocene rocks of the St Vincent Basin: Hallett Cove Sandstone, 'Aldinga', P19400-10 (radioles), P19447-54 (test fragments), P19354-64

(radioles), 'Maslin Bay', 1 test fragment AUGD Coll. Dry Ck Sands, 'Dry Ck bore at the abattoirs', P19334-5 (radioles).

REMARKS: This form is very similar to the living SE. Australian species *G. tubaria*. Because of the great variation which obtains in this latter species, it seems that none of the distinctions originally seen by Chapman and Cudmore in their species is valid. Thus H. L. Clark (loc. cit.) concluded that 'For stratigraphical purposes, it may be as well to accept the species, but sufficient well preserved material would probably show that the specific characters are hardly sufficient to warrant separation from *tubaria*'. However, the test of *G. tubaria hallettensis* is readily distinguished by the very much larger ambulacral plates, of which usually 7 are present opposite the highest interambulacral plates. From Mortensen's (1928, p. 157) table of measurements, it can seen that the number in adult specimens of *G. tubaria tubaria* is 10-12, while only in specimens of h.d. 14 mm or less are there as few as 7. The radioles of *G. tubaria hallettensis* also appear to lack the extreme ornamentation of those of *G. tubaria tubaria*, but this feature is extremely variable in the living form. Because of the close similarity, *hallettensis* is here regarded as a subspecies of *G. tubaria*.

G. mortenseni Chapman and Cudmore is a junior primary homonym of *G. mortenseni* Koehler. The name here substituted is derived from the type formation, the Hallett Cove Sandstone.

THE *G. murrayensis-G. tubaria* LINEAGE:

The similarity in morphology of *G. murrayensis, G. tubaria hallettensis* and *G. tubaria tubaria* suggests that these are a closely knit species group, and, from the stratigraphical occurrence of the forms, there is little doubt that they represent a phyletic series. This appears to be the first reasonably documented cidarid lineage noted. The trends exhibited by the lineage are:

1. Increase in size of the test. The older Longfordian specimens of *G. murrayensis* usually are no more than 12 mm in h.d., although some of the tests from the Port Willunga Beds are larger. From the Batesfordian and Balcombian Morgan Limestone the tests are up to 25 mm in h.d., although usually they are smaller. The fragments of *G. tubaria hallettensis* indicate that the test grew to a maximum h.d. of *c.* 35 mm, while *G. tubaria tubaria* grows to a size of over 60 mm, although normally adults are about 40 mm in h.d.

2. Increase in number of interambulacral plates. *G. murrayensis* has up to 6 or 7 plates in each vertical column. The fragments of *G. tubaria hallettensis* suggest 9 or 10 were present. *G. tubaria tubaria* has up to 13 but normally a few less than this.

3. Increase in number of ambulacral plates. 7 ambulacral plates are opposite the highest interambulacral plate in *G. murrayensis* (5 in the smaller varieties). Up to 8 are seen in *G. tubaria hallettensis*, and in *G. tubaria tubaria* there are as many as 13, although 10 may be present in some large specimens.

4. Ambulacral ornament. There is a slight decrease in the complexity of the secondary ambulacral ornament through the lineage.

5. Radioles. The radioles become more strongly ornamented through the lineage, although there is some reversal of this trend in *G. murrayensis*. They remain almost constant in size, and so become relatively shorter in relation to the test size.

6. Interambulacra. Accompanying the increase in the number of interambulacral plates, the lowermost scrobicules become confluent in the youngest members of the lineage. The *Stereocidaris*-like character of bare and incised upper horizontal

sutures persists through the lineage (*G. tubaria* alone of the living species of *Goniocidaris* possesses this feature), although the rudimentary upper scrobicules are apparently lost in *G. tubaria hallettensis*, and certainly are absent in *G. tubaria tubaria*.

Of these trends, phyletic increase in size is perhaps the most widely acknowledged evolutionary trend in invertebrates (cf. Newell 1948), and similarly trends 1-3 may be considered as allomorphic. Apart from size increase, the trends in the lineage are not obviously adaptive, although the increase in the number of ambulacral podia may well have been necessary for the respiratory efficiency of the larger urchins.

Although *G. murrayensis* undergoes a certain increase in size during its history, it is apparently replaced by (or perhaps overlaps the range of) the closely related *G. tubaria hallettensis* in the Cheltenhamian and this form persisted until at least Middle Pliocene times. *G. tubaria tubaria* is known only as the living form. The lineage thus appears to have progressed by a marked 'saltation' in the Cheltenhamian.

The interpretation of this seems clear. Mayr (1954), after discussing speciation in echinoids, concluded that (p. 16) 'geographic speciation is the principal, if not the exclusive speciation mechanism in most marine animals'. It would seem, therefore, that the replacement of a particular species by a very closely related form in the geological record should be interpreted as the invasion of the particular area by an allopatric population which replaces the earlier form (cf. Fleming 1957).

There is some evidence to support this interpretation here. The radioles of the youngest form of *G. murrayensis* from the Cheltenhamian differ from the older form in that the ornament is more subdued and the collars are long. On the other hand, the radioles of *G. tubaria hallettensis* recall those of the older forms of *G. murrayensis* both in their ornament and collars.

The present collection suggests that *G. murrayensis* and *G. tubaria hallettensis* were sympatric rather than allopatric. Both are known from 'Tramway cutting, Mississippi Ck', a locality of Cheltenhamian age.

Goniocidaris (?) pentaspinosa Chapman & Cudmore

(Pl. LXV, fig. 1, 4-16; Fig. 4h)

Goniocidaris pentaspinosa Chapman and Cudmore *in* Chapman 1928, p. 91-2 (*partim*), Pl. 11, fig. 74 a-f, (*non*) fig. 74g; Chapman and Cudmore 1934, p. 137-8 (*partim*), Pl. 14, fig. 19, (*non*) fig. 18; H. L. Clark 1946, p. 293 (*partim*); Fell 1954, p. 11 (*partim*).

DIAGNOSIS: Moderately large, tapering and somewhat fusiform radioles, with simple terminations, and usually polygonal in cross-sections, with ridges formed by thickening of the cortex at the angles. Thorn-like projections sometimes developed along these ridges which are poorly developed in the more fusiform varieties.

TYPE SPECIMEN: Chapman and Cudmore (1928) originally figured as syntypes of this form 6 radioles from Grices Ck and an interambulacral zone from Neumerella. This latter was subsequently (1934) identified as belonging to *G. murrayensis*, and Chapman and Cudmore then figured 5 radioles from Grices Ck as paratypes, and substituted what was termed a 'neotype' (a test fragment from Wongulla) for the wrongly identified specimen from Neumerella.

It is nowhere stated whether the radioles originally illustrated were the group subsequently figured (1934, fig. 19) from the same locality as paratypes. Despite the crudeness of the original illustrations, it does seem that most of the radioles are the same. However, in the original figures, the radioles shown in fig. 74d-e cannot be matched with radioles in the subsequent figure, and it would seem that the largest

radiole in (1934) fig. 19 has been substituted for these two radioles. Fig 74d, however, corresponds with the proximal portion of the later illustrated spine, and fig. 74e appears to represent a fragment rather than a small radiole. As the combined length of radiole in 74d-e corresponds with the length of the subsequently illustrated radiole, it is suggested that the groups of radioles are, in fact, the same.

As lectotype of *G. pentaspinosa* the radiole illustrated by Chapman and Cudmore (1928, Pl. 11, fig. 74b) is here chosen. This presumably was re-illustrated as the right-hand radiole of their (1934) Pl. 14, fig. 19 and the group is catalogued as P13718.

Description of Topotype Radioles: The radioles are long, slender and tapering, although some may be slightly fusiform. The neck is not apparent while the length of the collar is usually about ⅔ of the diameter of the proximal portion of the shaft. The milled ring is slightly expanded and fairly prominent. The shafts have a polygonal cross-section, which is often accentuated by the ridges along the angles bearing small, distally directed denticles. The shafts taper uniformly to a distal point. The outer surface of the shaft is remarkably smooth and glossy, but has a distinctly striate appearance, due to the transpareney of the cortical layer through which the lamellar zone is clearly visible. Cortical hairs apparently absent.

In transverse section the medullary zone is narrow (*c.* ⅓ of the diameter of the shaft), whereas the cortex layer (Fig 4h) is relatively thick, and thickens markedly to form the longitudinal ridges at the angles.

Variation: Radioles from different horizons and localities fall into three well-marked groups. These are:

Var. A. Long and slender forms which often possess well-marked dentieulations along the longitudinal ridges. Radioles of this group often show what is apparently traces of original colour banding. Radioles from the type locality belong here.

Var. B. These radioles are more robust and more fusiform than Var. A, although they are comparable in length. They lack dentieles at the base of the shaft.

Var. C. From usually older horizons the radioles are much shorter and distinetly fusiform, with the lower part of the shaft expanded. The well-defined polygonal cross-section is absent, and the shaft may be serrated for most of its length. Radioles of this type occur with Var. B along the Murray R. Cliffs (Pl. LXV, fig. 16).

Synopsis of Material:

Var. A.

'Griees Ck', P19376-7, P19429-46, Balcombian; 'Baleombe Bay', P19386-94, Baleombian; 'Murghebolue Sec. 4A', P19918-25, ? Balcombian; 'Orphanage Hill', Fyansford Clay, P19955, Balcombian; '2½ miles W. of Gellibrand', Gellibrand Clay, P18378-9, ? Baleombian; 'Gellibrand', Gellibrand Clay, P19904-5, ? Balcombian; 'Altona Coal Shaft', P19948, Balcombian.

Var. B.

'Neumerella railway eutting', P18381-3, Bairnsdalian.

From localities along the Murray R. Cliffs, S.A.:

Mannum Formation, Longfordian.

'Murray R. Cliffs from Wongulla to Mannum', P19705-24.

Morgan Limestone, Batesfordian and Balcombian.

'Lower Beds, Morgan', P19830-40; 'Base of cliffs at Pelican Point, 4 miles below Morgan', P19882.

VAR. C.

'Aire Coast, AW.3', Calder R. Limestone, P19005, Janjukian; '1¾ miles NW. Mt Gambier (D.31)', Gambier Limestone, AUGD F15730, ? Janjukian; 'Torresdale, Holding's Old Quarry, Gambier Limestone', P19459-61, ? Janjukian; 'Lower beds, Muddy Ck', P14638, Balcombian.

From the Gippsland Limestone and probable equivalents of Batesfordian age:

'Skinner's, Mitchell R.', GSV 58909-10 (8 specimens), GSV 58911 (7 specimens), GSV 53240 (16 specimens); 'Mitchell R., P20120; 'Le Grand's Quarry', GSV 58912 (6 specimens); 'Marl pit 250 yds. W. Brock's Quarry, GSV 58913 (15 radioles); GSV 58914 (20 radioles).

REMARKS: The test-fragments with which Chapman and Cudmore associated these radioles, both in 1928 and 1934, are here identified as *G. murrayensis*. Like its descendant *G. tubaria*, the width of the interambulacral midzone is particularly variable in *G. murrayensis*. Specimens with narrow interambulacral midzones and with few secondary tubercles were identified as belonging to *G. pentaspinosa* by Chapman and Cudmore.

At present, no tests can be associated with *G.* (?) *pentaspinosa*, nor can these radioles be ascribed to any other species. It is possible that they belong to *Plocidaris prunispinosa* because they apparently lack cortical hairs, and because the two 'species' are usually found in association and show similar modifications in different localities. However, no radioles of the *pentaspinosa* type are associated with P13174, a test of *D. prunispinosa* which shows some radioles in position.

The radioles show no resemblance to those of *Goniocidaris* (particularly in their simple terminations) nor to any other described genus. However, the form must be retained in *Goniocidaris* provisionally.

Genus **Austrocidaris** H. L. Clark

Temnocidaris Agassiz 1863, p. 18.
Austrocidaris H. L. Clark 1907, p. 212.
? *Ogmocidaris* Mortensen 1921, p. 143.
Austrocidaris H. L. Clark, Mortensen 1928, p. 140. (*cum synon.*)
(*Non*) *Temnocidaris* Cotteau 1863, p. 355.

TYPE SPECIES: *Temnocidaris canaliculata* A. Agassiz by original designation (H. L. Clark 1907).

DIAGNOSIS: Small, *Goniocidaris*-like forms, with closely spaced, oblique pores. The wall between the pores is narrow, and apparently never perforate.

REMARKS: In dealing with the fossil material, the only attribute which distinguishes *Austrocidaris* from *Goniocidaris* is the obliquity of the pores. This is a general feature of the Ctenocidarina, but in most genera of this group the narrow wall between the pores is perforate, giving rise to a condition approaching conjugation. *Austrocidaris* and *Ogmocidaris* stand apart from the other genera of the Ctenocidarina, not only in lacking such a feature, but also in possessing sunken furrows along the median ambulacral and interambulacral sutures. Both the genera *Austrocidaris* and *Ogmocidaris* are to date apparently monotypic (see below) and are to be distinguished principally by the number of peristomial plates. It is thus doubtful whether *Ogmocidaris* should be maintained as a full genus.

The Ctenocidarina are a specialized group of living cidarids which, with the exception of *Ogmocidaris* and some species of *Aporocidaris*, inhabit Antarctic and sub-Antarctic seas to the apparent exclusion of other cidarids. The occurrence of this group in the early Miocene of Australia in an environment which was un-

doubtedly as warm as, if not warmer than, the present is noteworthy. It suggests that the migration of the Ctenoeidarina into the Antaretie eould be a relatively reeent oecurrenee, and also tends to negate palaeoelimatological arguments whieh could be based on the geological oeeurrenee of the group (cf. Fell 1954, p. 45).

The only eonvineing fossil etenocidarine which has been deseribed previously is *Notocidaris vellai* Fell from the Plioeene of New Zealand. In this ease even pedicellariae were obtained which elearly defined the affinities of the speeies.

Mortensen (1928) eonsidered it 'highly probable' that *Goniocidaris jorgensis* de Loriol, from the reputed Eoeene of Patagonia, belongs to the genus *Austrocidaris* and represents the aneestor of *A. canaliculata*. However, there is nothing in the original deseription whieh allies the form with the Ctenoeidarina rather than the Stereocidarina.

DISTRIBUTION: The common living species *Austrocidaris canaliculata* (Agassiz) is widely distributed through the sub-Antarctie Seas. Mortensen (1928) reeognized a further speeies *A. spinosa* Mortensen, from S. of the Falkland Is., whieh is to be distinguished from *A. canaliculata* by the radioles 'the eoarse thorns at the base of the upper primaries being the main distinguishing feature . . .'. There is little doubt that this form is an allopatrie subspeeies of *A. canaliculata*. The genus *Ogmocidaris* is more elearly monotypie, with the type speeies *O. benhami* Mortensen known only from New Zealand.

Austrocidaris operta sp. nov.

(Pl. LXI, fig. 5-6; Pl. LXIV, fig. 1-4, 8; Fig. 5 d-e)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-130 (*partim*), (*non*) figs.
Goniocidaris prunispinosa Chapman and Cudmore 1934, p. 135-137 (*partim*), (*non*) figs.
Stereocidaris australiae (Duncan), H. L. Clark 1946, p. 290 (*partim*); Fell 1954, p. 10-11 (*partim*).
Goniocidaris prunispinosa Chapman and Cudmore, H. L. Clark 1946, p. 292 (*partim*); Fell 1954, p. 11 (*partim*).

DIAGNOSIS: A small *Goniocidaris*-like form with pits at the ends of the horizontal ambulaeral and interambulacral sutures. Upper horizontal interambulaeral suture bare, and the uppermost serobieule of eaeh zone rudimentary. Ambulacral plates very high; interporiferous traets eomplexly ornamented. Pores non-conjugate, very strongly oblique and mounted toward the top of the plates so that the horizontal ridge is poorly defined.

Radioles short (approximately the h.d. of the test), and eomparatively thiek. Collar and neek short, with the shaft ornamented by a few irregularly placed thorns.

TYPE SPECIMEN: Holotype P18608, an interambulaeral zone with ambulaeral columns, from the 'Polyzoal limestone, Beaeh N. of Bird Roek, Torquay', i.e. Zeally Limestone, Longfordian.

DESCRIPTION: The ambulacra are slightly sinuate and up to 35% the width of the interambulacra. The poriferous traet is about ½ the width of the interporiferous tract, but, unlike other cidarids, is poorly defined, with a seeondary tubercle of the interporiferous tract almost alternating with the innermost pores (Fig. 5d). The pores themselves are small, very strongly oblique and closely spaeed, with the wall between rising to a well-marked elevation. There is no horizontal ridge above the pores, but the lower outer corner of eaeh plate is slightly depressed. Toward the ambitus the interporiferous traet is ornamented by up to 5 secondary tubereles with a slightly enlarged marginal tuberele. 'V'-shaped pits, whieh widen medianly, mark

the horizontal sutures. These pits apparently extend on to the plates of the neighbouring ambulacral column, for the median angle of each plate is notched, imparting a scalloped appearance to the margin of the median ambulacral fracture.

In the interambulacra (Fig. 5e) the scrobicules are rounded and fairly deeply incised, although that of the uppermost interambulacral plate is rudimentary. The lowermost scrobicules tend to be ovate and confluent. The tubercles are small, smooth and perforate, and are mounted on high bosses which rise well above the level of the test. The scrobicular circles are prominent, with only a few secondary tubercles, more or less confined to the mid-zone, outside these. The uppermost horizontal sutures are bare and sunken while, elsewhere, deep 'V'-shaped pits are developed at the adradial and admedian ends of the horizontal sutures. As with those of the ambulacra, these tend to encroach on the plates of the adjacent column.

Association of Test and Radioles: A number of radioles were included in a batch of specimens containing test fragments of the species. As similar radioles occur with the test fragments in Gippsland, these are associated in the species.

Description of Radioles: The radioles are short and thick, with slightly tapered cylindrical shafts. The milled ring is well expanded and the collar is short, usually about ½ of the diameter of the shaft. The neck is not apparent. The shaft is ornamented by a few irregularly placed thorn-like projections.

Measurements: The holotype was derived from a test with h.d. *c.* 12 mm, v.d. *c.* 7 mm, diameter of apical system *c.* 9 mm, diameter of peristome *c.* 6 mm; 5-6 interambulacral plates in each vertical column. 4 ambulacral plates opposite an ambital interambulacral plate, but as many as 7 opposite the high uppermost interambulacral plate; 6 interambulacral plates are present in each vertical column.

Synopsis of Material:

Zeally Limestone, Torquay, Longfordian:

'Polyzoal Limestone, beach N. of Bird Rock', P18608 (holotype), P18606 (test fragment); 'Mouth of Spring Ck, Torquay, (i.e. '*Scutellina*' Limestone) P18639-42 (test fragments), P18643-60 (radioles).

From the Gippsland Limestone and its probable equivalents of Batesfordian age:

'Le Grand's Quarry, Glencoe', GSV 58929-31 (8 test fragments); 'Skinner's, Mitchell R', P20121-3, GSV 58932.

Radioles from various localities of probable Balcombian age:

'Murgheboluc Sec. 2B, P19894-902; 'Murgheboluc Sec. 4A, P19885-91; 'Altona Bay Coal Shaft', P19954; '2½ miles W. of Gellibrand R.', Gellibrand Clay, P19380; 'Grice's Ck', P19811-3.

Remarks: The species is largely characterized by the character of the ambulacra, and in particular the striking obliquity of the pores. This is variable, although normally it is developed to a degree such that the typical pattern of the cidarid ambulacra is interfered with (Fig. 5d). No comparisons with previously described species can be suggested.

Genus **Delocidaris** gen. nov.

Goniocidaris L. Agassiz and Desor, Chapman and Cudmore 1933, p. 135 *et seq.* (*partim*).

Type Species: *Goniocidaris prunispinosa* Chapman and Cudmore.

Diagnosis: Test moderately large, without pitted or incised sutures, and with sparse secondary interambulacral ornament. Primary tubercles small, and often partially crenulate. Scrobicules of uppermost interambulacral plates rudimentary.

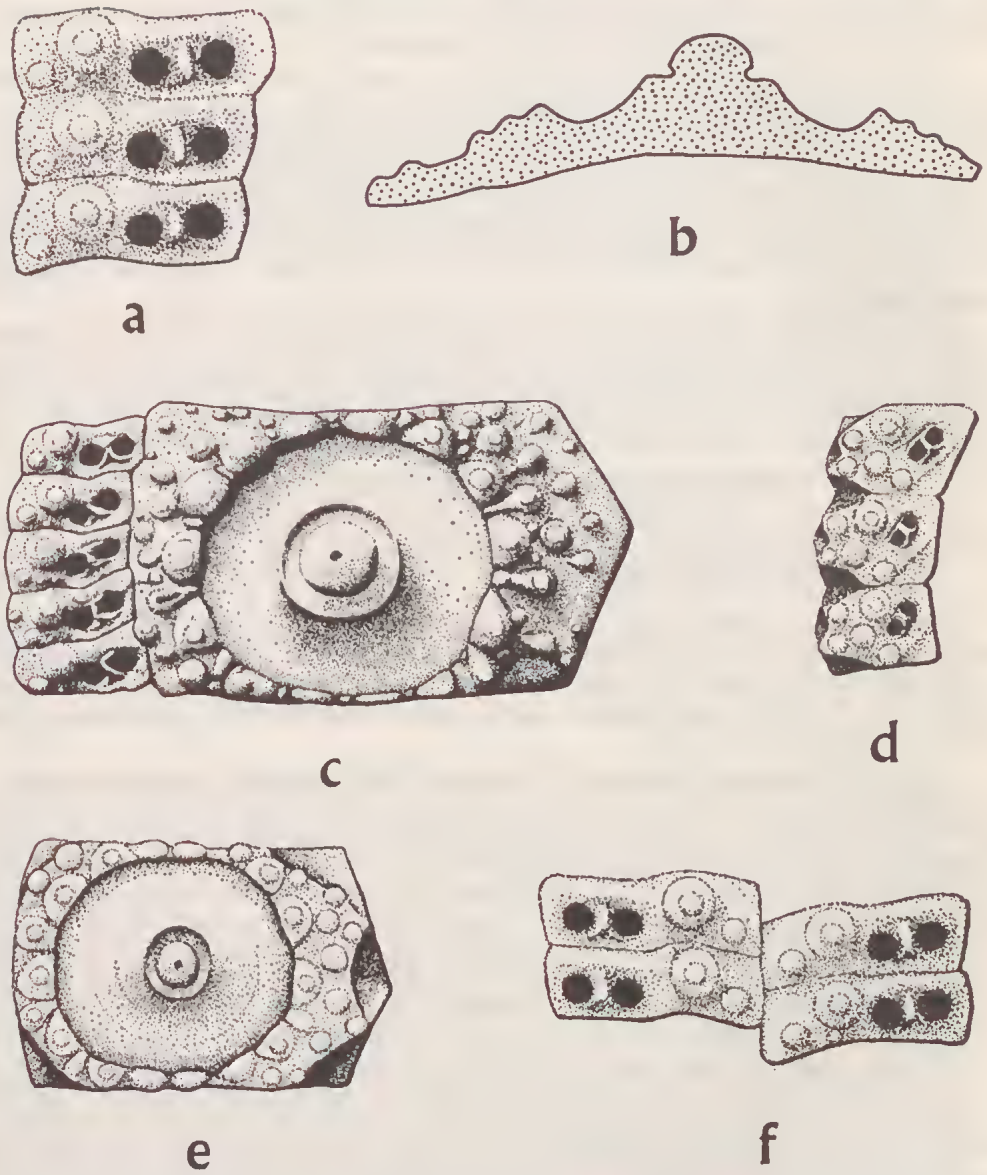

FIG. 5—*Delocidaris* and *Austrocidaris*. a-c, f, *Delocidaris prunispinosa* (Chapman & Cudmore). a, Ambital ambulacrum of P19411, × 15. b, Profile of GSV 58918, × 10. c, Isolated interambulacral plate and adjacent ambulacrum GSV 58918, × 10. f, Ambulacral plates of P13174, × 15. d-e, *Austrocidaris operta* sp. nov. d, Ambulacral plates of GSV 58930, × 15. e, Interambulacral plate of GSV 58930, × 15.

Pores non-conjugate. Radioles variably ornamented, often with prominent thorn-like projections, and flared, cup-shaped terminations. Collars long; cortex layer thick and glossy, apparently without cortical hairs.

REMARKS: The highly ornate radioles of *D. prunispinosa* provide the only basis for the original reference of the species to *Goniocidaris*. Even so, they are not typical of *Goniocidaris*, for they possess long collars and lack cortical hairs. The test lacks the grooved sutures of *Goniocidaris* and, indeed, is more closely akin to *Stereocidaris* in its upper rudimentary scrobicules and the partial crenulation of the tubercles. From *Stereocidaris*, however, the test of *Delocidaris* differs in the very sparse secondary tuberculation and the absence of depressed horizontal sutures. The radioles are unlike those of *Stereocidaris* in their ornate nature and apparent absence of cortical hairs.

No worthwhile comparisons can be made with other genera, nor have any other species been noted which could be referred to the genus. *Goniocidaris hebe* Fell (1954, p. 37), from the Oligocene of New Zealand, was considered by Fell to be closely comparable with *D. prunispinosa*. However, this species is described as possessing sutural grooves and so is apparently a species of *Goniocidaris*.

Delocidaris prunispinosa (Chapman & Cudmore)

(Pl. LVIII, fig. 6-9; Pl. LXIII; Fig. 5 a-c, f)

Goniocidaris prunispinosa Chapman and Cudmore *in* Chapman 1928, p. 90-1 (*partim*), Pl. 11, fig. 73 a-e; Chapman and Cudmore 1934, p. 135-7 (*partim*), Pl. 13, fig. 12 (16 radioles), 13-14; H. L. Clark 1946, p. 292; Fell 1954, p. 11 (*partim*).

DIAGNOSIS: A species of *Delocidaris* with interporiferous tract similar in width to the poriferous tract and ornamented by a regular vertical series of marginal tubercles, usually with two smaller internal tubercles on each plate. Up to 8 inter-ambulacral plates in each vertical column and 7 ambulacral plates opposite the highest interambulacral plate.

TYPE SPECIMEN: Chapman and Cudmore (1928) originally figured as syntypes of their *Goniocidaris prunispinosa* 7 radioles from Grices Ck, 4 radioles from Balcombe Bay, and an isolated interambulacral plate from the Gellibrand R. Subsequently, they figured a test with some attached radioles from Morgan as the holotype, and 17 radioles from Balcombe Bay as paratypes. 3 of the original syntypes (radioles) of *G. prunispinosa* from Grices Ck were included in the second batch of type specimens. One of these, that figured in their (1928) Fig. 73k, is here selected as lectotype of *G. prunispinosa*. This radiole was re-illustrated as the lower right-hand figure of Chapman and Cudmore's (1934) Pl. 13, fig. 12. With the remainder of the radioles in their Fig. 12, it is catalogued as P13715.

DESCRIPTION OF TOPOTYPE RADIOLES: The radioles are long and slender (probably greater in length than the h.d. of the test). The neck is not apparent, and the collar is comparatively long, usually equal to the diameter of the shaft. The milled ring is moderately expanded, prominent and strongly striate, and the acetabulum is often partly crenulate. The shaft is variably ornamented with distally directed thorns which often tend to be closely developed at each side of the shaft, where they may even coalesce to give irregular platey lateral wings which can be developed for most of the length of the shaft. Radioles with such wings tend to possess a prominent series of enlarged thorns toward the middle of what was apparently the adoral surface of the shaft. Other radioles may show no tendency to develop lateral wings. Where known, the distal termination is flared, occasionally very strongly, giving a wide, cup-shaped apical disc.

The cortical hairs are apparently absent, and the outer surface of the cortex is extremely glossy. The cortical layer is moderately thick and is transparent, giving the surface of the shaft a definite striate appearance as the underlying radial zone is usually visible.

VARIATION: The radioles of this species, as here interpreted, form a fairly closely knit series. However, a certain variation is seen when comparing the radioles of this species from the different localities. Those from the Murray R. Cliffs tend to be larger, more robust and generally more sparsely ornamented than do those from Grices Ck and Balcombe Bay. The distinctions, however, are so slight, that they may well have arisen as the result of the unrepresentative nature of available collections.

Far more obvious are the distinctions of the radioles from the Batesfordian horizons in Gippsland. These are very much shorter and more robust than the typical forms, and also tend to be more uniformly ornamented with thorns. The association with test fragments indentical with the typical *D. prunispinosa* is supported by often partially crenulate acetabula. Provisionally this older form is recognized as *D. prunispinosa* var. B.

Several radioles from the Lower Maude Beds apparently also belong to this species, although the shafts, which possess longitudinal ridges of thickened cortex, suggest to some extent those of *G.* (?) *pentaspinosa*. For the present, these are identified as *D. prunispinosa* var. C. Test fragments of the species are unknown from this locality.

ASSOCIATION OF TEST AND RADIOLES: One specimen (P13174) from the Morgan Limestone shows the association of test and radioles. This is the only known cidarid from the Australian Tertiary showing the radioles largely preserved in position. The partial crenulation of the tubercles also allows confident association of test and radioles.

DESCRIPTION OF TEST: The test is small and somewhat depressed. The ambulacra (Fig. 5 a, f) are slightly sinuate, and up to ¼ the width of the interambulacra. The poriferous tract is similar in width to, or slightly wider than, the interporiferous tract and is not sunken below its level. The non-conjugate pores are rounded and very slightly oblique, with the wall between rising to a very prominent elevation. The interporiferous tract is ornamented by a very regular series of large marginal tubercles, with a single internal tubercle at the lower corner of each plate. Occasional granules are also present. The median zone of the ambulacra tends to be unornamented, with the median suture slightly sunken; however, no groove is present, nor are pits developed.

In the interambulacra (Fig. 5c) the scrobicules are comparatively small and rounded, with a tendency for those of the most adoral plates to be confluent. They are mounted adradially so that the interambulacral midzone is wide. The scrobicule of the uppermost plate of each column is usually rudimentary. They are not incised and thus the bosses rise well above the level of the test. The parapets are wide, and may show traces of crenulation particularly on those plates above the ambitus. The scrobicular tubercles are fairly prominent and closely spaced, while the secondary tubercles outside of the scrobicular circle are distant, so that the median zone is virtually unornamented. The median interambulacral suture tends to be depressed.

MEASUREMENTS: P13174, a slightly crushed test from Wongulla, has the following measurements: h.d. 29 mm, v.d. 15 mm, diameter of peristome *c.* 12·5 mm, diameter of apical system *c.* 14 mm; largest test fragment (Morgan Limestone) from

a test with h.d. *c.* 32 mm; longest radiole from same horizon 37 mm long; up to 8 interambulacral plates in each vertical column, 7 ambulacral plates opposite the highest interambulacral plate.

Synopsis of Material:

Var. A.

'Balcombe Bay', P19790-809 (radioles), P19395-9 (radioles), P19412-6 (radioles), Balcombian; 'Red Hill, Shelford', P19131-41 (radioles), P19906-9 (radioles), Balcombian; 'Clifton Bank, Muddy Ck', P19966-9 (radioles), Balcombian; 'Orphanage Hill', P19956-7 (radioles), Balcombian; Altona Coal Shaft, P19949-53 (radioles), Balcombian.

From localities along the Murray R. cliffs, S.A.:

Mannum Formation, Longfordian.

'Lower beds, Mannum to Wongulla', P19815-29 (radioles); 'Wongulla', P19327-42 (test fragments).

Morgan Limestone, Batesfordian and Balcombian.

'Lower beds, Morgan', P19411 (test fragment), P13174 (test), P19855-64 (radioles); '4 miles below Morgan', P19976-7 (radioles), P19382-4 (radioles).

Var. B.

From the Gippsland Limestone and its probable equivalents of Batesfordian age: 'Le Grand's Quarry, Glencoe', GSV 58915-7 (43 radioles), GSV 52531 (3 test fragments; 4 radioles), GSV 57429 (12 test fragments), GSV 58918-9 (41 test fragments); 'Marl Pit, 250 yds W. Brocks Quarry', GSV 58920 (24 test fragments), GSV 58921 (20 test fragments); 'Skinners, Mitchell R.', GSV 58922 (13 radioles), GSV 58923 (4 test fragments).

Var. C.

'½ mile S. Lethbridge', (? TM 3, Singleton 1941, p. 71, fig. 12); 'Lower Maude Beds', Janjukian or Longfordian, P18532-9 (radioles).

No specimens of *D. prunispinosa* have been located from the following localities whence Chapman and Cudmore list their species; Sorrento Bore, Fischer Point, Native Hut Ck, Waurn Ponds, Ocean Grove, Neumcrella, Grange Burn, Dartmoor, Millicent, Aldinga.

Genus **Menocidaris** gen. nov.

Type Species: *Menocidaris compta* gen. et sp. nov.

Diagnosis: Moderately large forms with prominent smooth tubercles and non-conjugate pores; scrobicular tubercles with internal ridges similar to *Phyllacanthus*. Peristome with width similar to apical system. Pores non-conjugate. Radioles long and slender, ornamented with distally directed flanges, which distally give way to low serrated ridges; collars long; cortical hairs forming a spongy coat.

Remarks: *Menocidaris compta* includes the radioles which were identified by Chapman and Cudmore as belonging to their *Chondrocidaris clarkii*. As noted previously (Part I, p. 214) the tests of *'C.' clarkii*, on which the species was based, belong to the genus *Phyllacanthus*.

Although the ornament of these radioles is suggestive of the living genus *Chondrocidaris*, H. L. Clark (1946) has pointed out that they are very much more slender, and so questioned their assignment to *Chondrocidaris*. They also differ from those of *Chondrocidaris* in their shorter collars and their coat of cortical hairs. The real distinctions of the genera, however, lie in their test characters, for *Chondro-*

cidaris has conjugate pores and highly specialized secondary tubercles. Indeed, the test of *Menocidaris* resembles *Stylocidaris*, particularly *S.* (?) *scoparia* which also has ridged scrobicular tubercles. No worthwhile comparison with other cidarid genera can be made.

Radioles which may be assigned confidently to *Menocidaris* have been recorded from Miocene strata elsewhere. Together with *'Chondrocidaris' clarkii* these afford the basis for the record of the fossil occurrence of the rare living Indo-Pacific genus *Chondrocidaris*. They include those figured by Cottreau (1907, Pl. 5, fig. 7-7a) from the Miocene of Madagascar and those described by K. Martin (1885, p. 287, Pl. 15, fig. 293 a-c) as *Phyllacanthus sundaica* from the Miocene of Java. Mortensen (1928, p. 492) drew attention to the resemblance of these radioles with *Chondrocidaris* and subsequently Jeannet and R. Martin (1937, p. 221-2) referred *P. sundaica* to *Chondrocidaris* with the Madagascar radioles placed in synonymy. Fell (1954, p. 14) also lists these occurrences as representing *Chondrocidaris*. *'P.' sundaica* is here referred to *Menocidaris* which it resembles much more closely than *Chondrocidaris*. *Chondrocidaris problepteryx* H. L. Clark (1945, p. 314), based on fragmentary radioles from the Miocene of Lau, probably should also be included in *Menocidaris*. No fossil representatives of *Chondrocidaris* are known.

'Dorocidaris' henjammensis Clegg (1933, p. 17-8, Pl. 2, fig. 3 a-c) from the Miocene Mekran 'Series' of India, and from Henjam Is. in the Persian Gulf, is based on a test fragment, which, as illustrated, appears to agree closely with the test characters of *Menocidaris*.

DISTRIBUTION: *Menocidaris* is confined to the Miocene of the Australasian and Indo-Pacific regions (Madagascar, Indonesia, Fiji, ? India, ? Persian Gulf).

Menocidaris compta sp. nov.

(Pl. LIX, fig. 5; Pl. LXI, fig. 1; Pl. LXVII, fig. 1; Fig. 6)

Chondrocidaris clarkii Chapman and Cudmore 1934, p. 141-2 (*partim*), Pl. 15, fig. 31 (radioles), (*non*) Pl. 13, fig. 15-17; H. L. Clark 1946, p. 248 (*partim*); Fell 1954, p. 11 (*partim*).

DIAGNOSIS: A species of *Menocidaris* with narrow interambulacral midzone, and with narrow interporiferous tracts ornamented by a regular series of large marginal tubercles with occasional small internal tubercles.

TYPE SPECIMEN: Holotype P22315, an interambulacral zone labelled as collected with the radioles of *Chondrocidaris clarkii*, 'Morgan', Morgan Limestone, Balcombian or Batesfordian.

DESCRIPTION: The ambulacra are sinuate and about ⅓ the width of the interambulacra. The interporiferous tract is slightly narrower than the poriferous tract. The large, almost contiguous marginal tubercles form a regular vertical series, and may be augmented by a single small internal tubercle on each plate (Fig. 6c). The rounded pores are slightly oblique and non-conjugate, with the wall between rising to a low crest, whereas the transverse ridge above the pores is low.

Up to 8 interambulacral plates in each vertical column. The large shallow scrobicules are subquadrate, and the ambulacral midzone is exceedingly narrow, so that secondary tubercles outside the scrobicular circle are few (Fig. 6b). The smooth primary tubercles are large and prominent, and the bosses rise well above the level of the test. Each of the prominent scrobicular tubercles possesses a well-defined ridge running from the mamelon across the boss to the edge of the scrobicule of its primary tubercle.

RADIOLES: The holotype is labelled in the National Museum collections as being originally associated with the group of radioles illustrated as *Chondrocidaris clarkii* by Chapman and Cudmore.

The radioles are long and slender, cylindrical or slightly tapered and somewhat flattened, and attain twice the h.d. of the test. The shaft is ornamented proximally

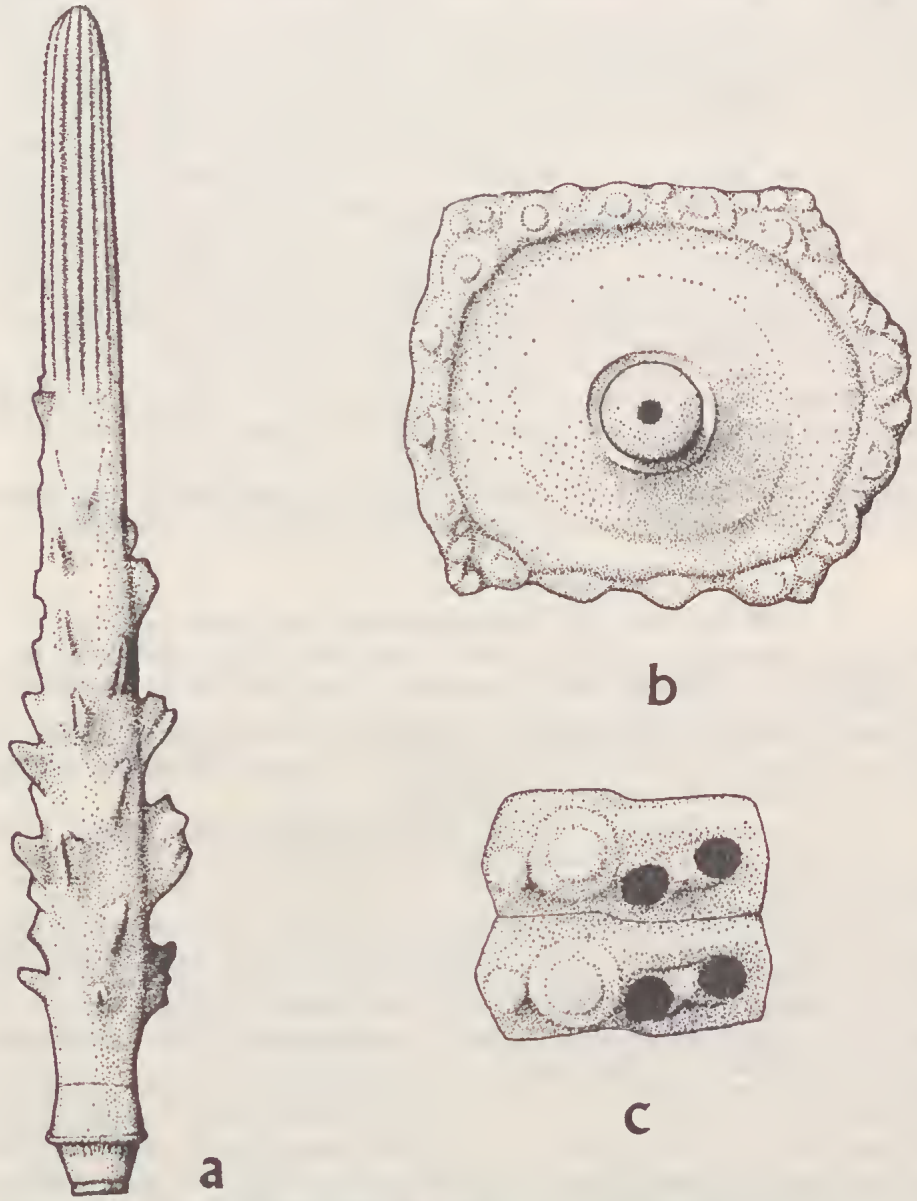

FIG. 6—*Menocidaris compta* gen. et sp. nov. a, Radiole based on P13713, × 4. b, Interambulacral plate and adjacent ambulacrum of holotype P22315, × 10. c, Ambulacrum of holotype, × 25.

by distally directed flattened thorns which tend to be aligned in longitudinal series on the adapical surface and along each side of the shaft where they coalesce to form lateral flanges. Distally this ornament usually gives way to fine serrated ridges which end in a blunted apex. The collar is up to 3 mm long, whereas the neck is short and is seldom apparent. Traces of a thick coat of spongy cortical hairs extending well up the flanks of the flanges are present in some specimens.

MEASUREMENTS: The holotype P22315 was derived from a test with the following inferred measurements: h.d. *c.* 28 mm; v.d. *c.* 15 mm; diameter of apical system *c.* 13 mm; diameter of peristome *c.* 13 mm; 10 ambulacral plates opposite highest interambulacral plate. P19789 was derived from a test with h.d. *c.* 35 mm.

SYNOPSIS OF MATERIAL:

Murray R. Cliffs, Wongulla to Mannum, ? Mannum Formation, Longfordian, P19928-33.
'Morgan', Morgan Limestone, Balcombian/Batesfordian, P19789, P22315 (test fragments); P13713 (6 radioles), P19943-7.

REMARKS: The test of *M. compta* resembles that of *Phyllacanthus duncani* in the large tubercles, well-defined and ridged scrobicular tubercles, narrow interambulacral midzones and narrow interporiferous tracts. The simpler ambulacral ornament, the non-conjugate pores and fewer ambulacral plates, however, distinguish *M. Compta.*

Cidarid Fragments

In this section a number of fragmentary species, either generically indeterminate or inadequately characterized, is listed. These are included for completeness, and further indicate the remarkable abundance and variety of cidarids in the SE. Australian Tertiary.

Corona sp. 1

(Pl. LXII, fig. 1)

Prionocidaris scoparia Chapman and Cudmore 1934, p. 134-5 (*partim*), (*non*) figs.

MATERIAL AND HORIZON: One interambulacral zone (P19788) and 6 interambulacral plates (P19272-7), 'Aldinga, lower beds', probably Port Willunga Beds.

DESCRIPTION AND REMARKS: A moderately large species (h.d. *c.* 40 mm) with up to 6 interambulacral plates in each vertical column. Scrobicules shallow and the primary tubercles are smooth and prominent. The interambulacral midzone is wide and is furrowed by closely spaced sub-horizontal grooves, between which are mounted small secondary tubercles. The interporiferous tract is narrow and the pores are non-conjugate, with a well-marked transverse ridge above the pores.

This distinctive species is probably best included in *Stylocidaris.* One of the groups of radioles described as Radiolus sp. 5-7 could belong to this test.

Corona sp. 2

(Pl. LXI, fig. 4, 7)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-130 (*partim*), (*non*) figs.
Goniocidaris murrayensis Chapman and Cudmore 1934, p. 138-9 (*partim*), (*non*) figs.

MATERIAL AND HORIZON: One interambulcral zone (P13857) and 4 test fragments (P19293-4; P19303-4), 'Aldinga, lower beds', probably Port Willunga Beds.

DESCRIPTION AND REMARKS: A moderate sized form (h.d. *c.* 30 mm) with up

to 6 interambulacral plates in each vertical column. The poriferous tracts are depressed and the interporiferous tract is wide and complexly ornamented. Scrobicules small, very deeply incised, and are mounted toward the adradial sides of the columns leaving a wide interambulacral midzone. The primary tubercles are smooth and the bosses are small, just rising above the level of the test. The pores are nonconjugate with the upper transverse ridges very high and prominent. Pits are developed at the median ends of the horizontal interambulacral sutures and similar pits may be present in the ambulacra, although this feature appears to be variable.

This form belongs to the group of species here included in *Stereocidaris* and *Goniocidaris*. It shows closer affinity with *Goniocidaris* than do *Stereocidaris cudmorei* and *Stereocidaris* sp. C, for naked sutural pits may be developed in the ambulacra as well as in the interambulacra.

The extreme development of the horizontal ridges above the pores is a striking feature of the species. This character is also known in some living goniocidarinids, particularly in *Goniocidaris florigera*, where the pore arrangement simulates conjugation. Indeed, Lambert and Thiéry (1910, p. 153) took *Petalocidaris* Mortensen (based on *G. florigera*) to be a good genus characterized by conjugate pores. However true conjugation of the pores is not known in the Goniocidarina.

Corona sp. 3

(Pl. LXVI, fig. 5)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) figs.

Material and Horizon: Isolated interambulacral plates (P19290-2, P19295-6, P19298-301, P19305-8, P19465-9), 'Aldinga, lower beds', probably Port Willunga Beds.

Remarks: These plates, obviously derived from a species of *Stereocidaris*, appear to represent a form close to *Stereocidaris* sp. B from the Browns Ck Clays. It would, however, be unwise to identify the present fragments with those from the Aire Coast for they are of a smaller form, which possesses more closely spaced secondary tubercles. More than one species may be represented in these fragments.

Radiolus sp. 1

(Pl. LXVII, fig. 7-8)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) fig.

(?) *Prionocidaris marshalli* Fell 1954, p. 54, Pl. 8, fig. B-C, I; Pl. 9, fig. C.

Material and Horizon: 'Hamilton Ck, Hordern Vale', P18987-9; 'Browns Ck', P20151, Browns Ck Clays, 'Pre-Janjukian'.

Description and Remarks: The shaft is apparently very long and cylindrical with irregular, distally directed thorns. Although the base is missing in all specimens, traces of a very long collar (3 mm +) are seen in some radioles. The cortex layer is very thin and glossy, and imparts to the surface of the shaft an enamelled appearance, whereas the collar is dark and matt in texture.

Fell (loc. cit.) described a very similar group of fragmentary radioles from the Middle Eocene of New Zealand as *Prionocidaris marshalli*. The character of the very thin cortex layer, which apparently lacked cortical hairs, precludes the identification of this form as *Prionocidaris* and, indeed, most other genera. It does, however, suggest a general comparison with the Histocidarina in which this feature is typical. Some confirmation of this suggested relationship would be found in the character of the acetabulum—whether crenulate or not. To date, however, it

appears that all speeimens of this form are too imperfeet to show this feature. Certainly these radioles eannot be taken as indieative of the oeeurrenee of *Prionocidaris* in the Australasian Tertiary.

Radiolus sp. 2

(Pl. LXVII, fig. 2)

Smooth spines, *incertae sedis,* Chapman and Cudmore 1934, p. 142-3; Pl. 14, fig. 24 (3 radioles).

MATERIAL AND HORIZON: 'Aldinga', P19417-8, ? Port Willunga Beds; 'Lethbridge' (? TM3), P18543-5, Lower Maude Beds, Janjukian; 'Lower beds, Wongulla to Mannum', P19369-75, Mannum Formation, Longfordian.

DESCRIPTION AND REMARKS: Small eylindrieal or tapering radioles whieh possess somewhat glossy shafts, short eollars, and smooth aeetabula.

While the smooth, thin, even eortex layer immediately suggests a relationship with sueh living genera as *Calcocidaris* or *Homalocidaris*, in the absenee of knowledge of test eharaeters, the true affinities of this form must remain obseure.

Radiolus sp. 3

(Pl. LXVII, fig. 3)

MATERIAL AND HORIZON: *'Turritella* Bed', Table Cape, Tasmania, P19881, Janjukian.

DESCRIPTION AND REMARKS: The single speeimen is the proximal portion of a large radiole, with a eomparatively long eollar, an expanded milled ring and smooth aeetabulum. The shaft is smooth and the eortex layer is regular in thiekness.

This is obviously different from the smooth radioles of Radiolus sp. 2, and reealls more elosely the radioles of the etenoeidarinid *Homalocidaris* in the expanded milled ring.

Radiolus sp. 4

(Pl. LXVII, fig. 10)

Goniocidaris prunispinosa Chapman and Cudmore 1934, p. 135-7 (*partim*), (*non*) figs.

MATERIAL AND HORIZON: 'Forsyth's, Hamilton', P19936-42, Grange Burn Formation, Kalimnan.

DESCRIPTION AND REMARKS: Comparatively small, somewhat fusiform radioles, with short eollars, poorly defined milled rings and smooth aeetabula. The shaft is ornamented by well-spaeed tubereles and may possess lateral wings. Traees of a thiek eoat of eortieal hairs usually present between the tubercles.

While resembling the radioles whieh have already been deseribed as *Eucidaris strombilata felli* (Part I, p. 202), these are obviously different as they possess lateral wings and very irregular ornament. These features would seem to preelude their plaeement in *Eucidaris* and in some respeets they reeall rather the highly ornate radioles of the Australian Tertiary speeies of *Stereocidaris.* This group of radioles appears to resemble elosely those deseribed as *Cidaris mertoni* Döderlein (1911, p. 236, Pl. 9, fig. 3-8; Currie 1924, Fig. 18-30) from the Plioeene of the Aru Is.

Radiolus sp. 5

(Pl. LXVII, fig. 9)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) Pl. 12, Pl. 15, fig. 34-5, (*non*) fig. 32, 36.

MATERIAL AND HORIZON: 'Aldinga, lower beds', P19761-73, P19548-62, ? Port Willunga Beds.

DESCRIPTION AND REMARKS: Long slender radioles with shafts ornamented by fine denticles arranged in longitudinal series in low ridges, between which are preserved traces of short simple cortical hairs. Rarely the denticles may be enlarged as small flange-like projections. The neck is relatively long, the collar short and the acetabulum smooth. The distal termination is simple.

These radioles probably belong to a species of *Stereocidaris*.

Radiolus sp. 6

(Pl. LXVII, fig. 12)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) Pl. 12, Pl. 15, fig. 36 a-b, (*non*), fig. 32, 34-5, 36e.

MATERIAL AND HORIZON: 'Aldinga, lower beds', P19477-513, P19534-46, ? Port Willunga Beds.

DESCRIPTION AND REMARKS: Moderately large cylindrical or slightly fusiform radioles with short collars and smooth acetabula. The shaft is ornamented by denticles and coarse thorns and the distal termination is expanded or cup-shaped.

These radioles apparently belong to a species of the *Stereocidaris-Goniocidaris* group.

Radiolus sp. 7

(Pl. LXVII, fig. 11, 13)

Stereocidaris australiae (Duncan), Chapman and Cudmore 1934, p. 127-30 (*partim*), (*non*) Pl. 12, Pl. 15, fig. 36e, (*non*) fig. 32, 34-5, 36 a-b.

MATERIAL AND HORIZON: 'Aldinga, lower beds', P19254-61, P19465-76, ? Port Willunga Beds.

DESCRIPTION AND REMARKS: Comparatively short often flattened and fusiform radioles usually with long collars and smooth acetabula. The shaft is ornamented with coarse denticles and irregular tubercles and lateral wings may be developed. The distal termination is tapered or slightly flared.

The ornament of the shaft suggests comparison with Radiolus sp. 4.

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Explanation of Plates

Figures × 1 unless otherwise stated.

PLATE LVIII

Fig. 1-5– *Stereocidaris australiae* (Duncan). (1) Holotype BM E42395, 'AW.5', Castle Cove Limestone, 'Pre-Janjukian'; (2) Radiole P19751, 'Point Flinders', Lower Glen Aire Clays, 'Pre-Janjukian', × 2; (3) Test fragment P18913, 'AW.5', × 2; (4) Radioles P18937-9, 'AW.5', × 2; (5) Radiole P18902, 'AW.5', × 2.

Fig. 6-9—*Delocidaris prunispinosa* (Chapman & Cudmore). (6) Radioles P18532-4, var. C, 'Lethbridge', Janjukian or Longfordian, × 2; (7) Interambulacral plate P19334 showing partial crenulation of the tubercle, 'Wongulla', ? Longfordian, × 2; (8) 9 radioles GSV 58915, var. B, 'Le Grand's Quarry, Glencoe', Batesfordian, × 2; (9) Radiole GSV 58916, var. B, same locality, × 5.

PLATE LIX

Fig. 1-3, 7-8—*Stereocidaris inermis* sp. nov. (1) Adapical, (2) Lateral, (3) Adoral views of holotype AUGD T363, 'Aldinga', Upper Eocene (2, unconventionally oriented); (7) Apical system of holotype, × 3; (8) Test fragment AUGD F15744, 'Aldinga', Upper Eocene, × 2.

Fig. 4—*Stereocidaris* (?) *intricata* sp. nov. Holotype P22319, 'Aldinga', Upper Eocene, × 2.

Fig. 5—*Menocidaris compta* gen. et sp. nov. Holotype P22315, 'Morgan', Batesfordian or Balcombian, × 3.

Fig. 6—*Stereocidaris fosteri* sp. nov. Holotype AUGD F15739, 'Maslin Bay', Upper Eocene, × 2.

PLATE LX

Fig. 1-5—*Stereocidaris cudmorei* sp. nov. (1) Test fragment AUGD F15736, × 2; (2) Test fragment AUGD F15732, × 2; (3) Holotype P19365, × 2; (4) Test fragment of abnormal specimen AUGD F15738, × 2; (5) Test fragment AUGD F15731, × 2. All specimens from the Upper Eocene Tortachilla Limestone.

PLATE LXI

Fig. 1—*Menocidaris compta* gen. et sp. nov. Adoral view of test fragment P19789, 'Morgan', Balcombian or Batesfordian, × 2.

Fig. 2-3—*Stereocidaris* sp. A. (2) Radioles P19578-9, 82, 89, 'AW.1', 'Pre-Janjukian'; (3) Radioles P19731-2, 7-8, same locality.

Fig. 4, 7—Corona sp. 2. (4) Test fragment P19293, 'Aldinga', Janjukian-Batesfordian, × 2; (7) Test fragment P13857, same locality, × 2.

Fig. 5-6—*Austrocidaris operta* sp. nov. (5) Radioles P18644-7, 'Spring Ck', Longfordian, × 2; (6) Holotype P18608, 'Beach N. of Bird Rock, Torquay', Longfordian, × 2.

Fig. 8-9—*Stereocidaris* (?) *hispida* sp. nov. (8) Test fragment AUGD F15746, 'Seaford', Janjukian/Batesfordian, × 2; (9) Holotype AUGD F15745, 'Maslin Bay', Upper Eocene, × 3.

Fig. 10-12—*Goniocidaris praecipua* sp. nov. (10) Adapical, (11) Lateral, (12) Adoral views of holotype P22316, 'Beach N. of Bird Rock, Torquay', Longfordian, × 3.

Plate LXII

Fig. 1—Corona sp. 1. P19788, 'Aldinga', Janjukian/Batesfordian, × 2.

Fig. 2-3, 6-12—*Goniocidaris murrayensis* (Chapman & Cudmore). (2) Test fragment P18531, 'Lethbridge', Janjukian or Longfordian, × 4; (3) Test fragment P19918, 'Murgheboluc', ? Balcombian, × 4; (6) Lateral; (7) Adapical; (8) Adoral views of AUGD 15728, 'Seaford', Janjukian/Batesfordian, × 3; (9) Test fragment AUGD 15734, same locality, × 3; (10) Test fragment AUGD 15733, same locality, × 3; (11) Test fragment AUGD 15735, same locality, × 3; (12) Test fragment AUGD 15729, same locality, × 3.

Fig. 4-5—*Stereocidaris* sp. A. (4) Isolated interambulacral plates P19343-6, 53, 'AW.1', Pre-Janjukian', × 2; (5) Shaft of radiole P19581, same locality, × 5.

Plate LXIII

Fig. 1-9—*Delocidaris prunispinosa* (Chapman & Cudmore). (1) Radioles P19395-9, var. A, 'Balcombe Bay', Balcombian, × 2; (2) Test fragment P19411, 'Morgan', Balcombian or Batesfordian, × 2; (3) Lateral view of test P13174, 'Morgan'; (4) Radioles P19412-6, var. A, 'Balcombe Bay', Balcombian, (uncoated), × 2; (5) Radioles P19815-8, var. A, 'Lower beds, Mannum to Wongulla', Longfordian, (uncoated), × 2; (6) Radioles P19790-3, var. A, 'Balcombe Bay', Balcombian, × 2; (7) Radioles P19949-50, var. A, 'Altona Coal Shaft', Balcombian, × 2; (8) Radiole P19976, '4 miles below Morgan', Balcombian or Batesfordian, × 2; (9) Radioles P19131-4, var. A, 'Red Hill, Shelford', Balcombian, (uncoated), × 2.

Plate LXIV

Fig. 1-4, 8—*Austrocidaris operta* sp. nov. (1) Radiole P18643, 'Spring Ck', Longfordian, × 2; (2) Radioles P19811-3, 'Grices Ck', Balcombian, × 2; (3) Radioles P19885-6, 'Murgheboluc 4A', ? Balcombian, × 2; (4) Test fragment GSV 58930, 'Le Grand's Quarry, Glencoe', Batesfordian, × 10; (8) Radioles P19894-6, 'Murgheboluc 2B', ? Balcombian, × 2.

Fig. 5-6—*Goniocidaris murrayensis* (Chapman & Cudmore). (5) Test fragment P19916, 'Morgan', Batesfordian or Balcombian, × 3; (6) Test fragment P19288, 'Wongulla', Longfordian, × 3.

Fig. 7, 9-11—*Stereocidaris* sp. B. (7) Radioles P18947, 50-51, 53, 59, 62, 71, 74, 76, 84, 'Hamilton Ck', 'Pre-Janjukian'; (9) Isolated interambulacral plates P18940-2, same locality, × 2; (10) Radioles P19910-11, 'Browns Ck', 'Pre-Janjukian'; (11) Shaft of radiole P18948, 'Hamilton Ck', × 5.

Plate LXV

Fig. 1, 4-16—*Goniocidaris* (?) *pentaspinosa* Chapman & Cudmore. (1) Radioles P18381-3, var. B, 'Neumerella Railway Cutting', Bairnsdalian, × 2; (4) Radioles P19386-8, var. A, 'Balcombe Bay', Balcombian, × 2; (5) Radioles P19376-7, var. A, ? showing original colour banding, 'Grices Ck', Balcombian, (uncoated), × 2; (6) Radiole P19955, var. A, ? showing original colour banding, 'Orphanage Hill', Balcombian, (uncoated), × 2; (7) Radiole P19948, var. A, ? showing original colour banding, 'Altona Coal Shaft', Balcombian, (uncoated), × 2; (8) Radiole P20120, var. C, 'Mitchell R.', Batesfordian, × 2; (9) Radiole P19005, var. C, 'AW.3'. ? Janjukian, × 2; (10) Radioles GSV 58909, var. C, 'Skinner's, Mitchell R.', Batesfordian, × 2; (11) Radioles AUGD F15730, var. C, '1½ miles NW. of Mt Gambier', ? Janjukian, × 2; (12) Radioles GSV 58912, var. C, 'Le Grand's Quarry, Glencoe', Batesfordain, × 2; (13) Radioles P19429-33, var. A, 'Grices Ck', Balcombian, × 2; (14) Radioles P19378-9, var. A, 'Gellibrand R.', ? Balcombian, × 2; (15) Radiole P14638, var. C, 'Muddy Ck', Balcombian, × 2; (16) Radioles P19705-9, var. B & C, 'Wongulla to Mannum', Longfordian, × 2.

Fig. 2—*Stereocidaris* sp. A. Distal ends of 2 radioles P19699-700, 'AW.1', 'Pre-Janjukian', × 2.

Fig. 3—*Stereocidaris fosteri* sp. nov. Test fragment AUGD F15740, 'Maslin Bay', Upper Eocene, × 2.

Plate LXVI

Fig. 1-2, 12—*Goniocidaris tubaria hallettensis* subsp. nom. nov. (1) Test fragment P19449, × 2; (2) Test fragment P19451, × 4; (12) Radioles P19400-5, × 2. Specimens from the Middle Pliocene Hallett Cove Sandstone.

Fig. 3, 8—*Stereocidaris* sp. C. (3) Oblique adapical view; (8) Lateral view of AUGD F15742, 'Aldinga', Upper Eocene, × 2.

Fig. 4, 6-7, 9-12—*Goniocidaris murrayensis* Chapman & Cudmore. (4) Radiole P19884, 'Murghebolue', ? Balcombian, × 2; (6) Shaft of radiole of stratigraphically older form P19883, 'Morgan', Batesfordian or Balcombian, × 5; (7) Shaft of radiole of stratigraphically younger form P19073, 'Tambo R., downstream from Swan Reach', Cheltenhamian, × 5; (9) Radioles P18419-21, 'Tramway Cutting', Cheltenhamian, × 2; (10) Radioles P19067-72, 'Tambo R., downstream from Swan Reach', Cheltenhamian, × 2; (11) Radioles P19865-70, 'Morgan', Batesfordian or Balcombian, × 2.

Fig. 5—Corona sp. 3. Test fragment P19465, 'Aldinga', Janjukian/Batesfordian, × 2.

Plate LXVII

Fig. 1—*Menocidaris compta* gen. et sp. nov. Radioles P19943-5, 'Morgan', Batesfordian or Balcombian, × 2.

Fig. 2—Radiolus sp. 2. Radioles P19417-8, 'Aldinga', Janjukian/Batesfordian, × 2.

Fig. 3—Radiolus sp. 3. Radiole P19881, '*Turritella* bed Table Cape', Janjukian, × 2.

Fig. 4-6—*Goniocidaris tubaria hallettensis* subsp. nom. nov. (4) Radioles P18417-8, 'Tramway Cutting', Cheltenhamian, × 2; (5) Termination of radiole P19401, 'Aldinga', Middle Pliocene, × 5; (6) Radioles P19334-5, 'Dry Creek Bore at Abattoirs', Middle Pliocene, × 2.

Fig. 7-8—Radiolus sp. 1. (7) Radiole P18989 (uncoated), 'Hamilton Ck', 'Pre-Janjukian', × 2; (8) Radiole P20151, 'Browns Ck', 'Pre-Janjukian', × 2.

Fig. 9—Radiolus sp. 5. Radioles P19771-3, 'Aldinga', Janjukian/Batesfordian, × 2.

Fig. 10—Radiolus sp. 4. Radioles P19936-7, 'Forsyth's Hamilton', Kalimnan, × 2.

Fig. 11, 13—Radiolus sp. 7 (11) Radioles P19258-61; (13) Radioles P19254-7, 'Aldinga', Janjukian/Batesfordian, × 2.

Fig. 12—Radiolus sp. 6. Radioles P19534-6, 'Aldinga', Janjukian/Batesfordian, × 2.